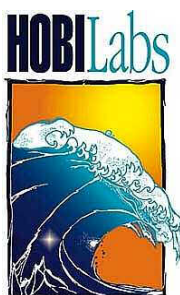


HydroRad

Multi-Channel Hyperspectral Radiometers

User's Manual

Revision 1.33G



**Hydro-Optics, Biology & Instrumentation
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Revisions

Version 1.33g, November, 2007

Update layout diagrams, section 2, add switch diagrams, section 7. Change references to HydroRad-D2 to HydroRad-E2, section 4. Update battery durances, section 5.3.1.

Version 1.33f, June, 2006

Add picture of HydroRad-D2 (name changed to –E2 in rev 1.33g), note about models without batteries.

Version 1.33e, June, 2005

Correct power consumption, section 5. Delete HyperTerminal, XMODEM and YMODEM from section 6

Version 1.33d, May, 2005

Add pin diagram, section 5

Version 1.33c, April, 2004

Improve descriptions of configurations, including optional shutter and daisy-chain connectors, and spectrometer performance. Change “DD” cable to “PDI”.

Version 1.33b, March 1, 2004

Correct obsolete references to HRCal in section 9.

Version 1.33a, February 9, 2004

Correct obsolete reference to the operation of the trigger switch in section 9.3

Version 1.33, September 25, 2003

Added limited firmware support for HydroRads without flash memory

Eliminated user selection of QuickAuto mode.

Expanded discussion of Auto integration parameters in section 8.2.1.

Version 1.31, August 1, 2003:

Major overhaul in all sections to accommodate Series 300 HydroRads and RadSoft.

Major change in the operation of the LogAuto command, see section 8.4.9.

Added description of Binary-CRC and Prompted-CRC data formats in 10.7.

Major change in the operation of the Trigger switch, see section 7.2.

Eliminated section (11), HRCAL.

Version 1.232a, February 19, 2002:

Revised HyperTerminal, and section (11), Windows Drag/Drop Mode

Version 1.232, October 10, 2001:

Start of revision tracking.

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1. PRECAUTIONS AND MAINTENANCE

1.1. Precautions

- **Handle the fiber optic cables with care.** Although the jackets are rugged, sharp bends can create the risk of breaking the fibers. Avoiding bending series 200 cables to less than a 6" radius, and series 300 cables to less than 3" radius. Never lift the instrument by the cables.
- Protect the fiber optic connectors (series 200 HydroRads only). Cover them with vinyl caps or leave fiber optic cables connected whenever possible. Do not immerse or spray the instrument without fiber optic cables installed.
- Use only silicone-based lubricants on electrical connectors. **Never use WD-40.**
- Do not use acetone or other harsh solvents to clean any part of the instrument.
- On Series 200 HydroRads, thoroughly clean the pressure port (under the lifting eye) with fresh water before storing the HydroRad.
- Avoid letting the instrument sit in direct sun for prolonged periods. If the water temperature is very different from the temperature on deck, let the instrument stabilize in the water for 10 minutes before collecting data.

1.2. General Cleaning

Upon removing the instrument from salt water rinse it thoroughly with fresh water.

1.3. Pressure Transducer

On series 100 & 200 HydroRads, the pressure transducer is underneath an array of four small holes in the lifting ring. Before storing the instrument, flush the transducer with a gentle stream of fresh water into the holes. A squeeze-bottle is ideal for the purpose. A low-velocity stream from a hose is also acceptable.

On series 300 HydroRads, the pressure transducer is located under a reservoir of silicone oil, which has a cap and a long thin tube sticking out of it. The reservoir may need occasional refilling; this is normally performed by HOBI Labs during regular maintenance.

1.4. Electrical Connectors

Occasionally spray the connector pins with silicone lubricant. **Do not use any petroleum-based lubricant, especially WD-40.** The connectors should mate smoothly without great force. Well-lubricated connectors also separate fairly easily; so always use the locking sleeves. NOTE: use care to avoid contaminating the optical connectors (series 200 only) with lubricant.

1.5. Fiber Optic Connectors (series 100 and 200 only)

When detaching and re-attaching a fiber optic connector (Series 100 & 200 only), there is always the possibility that contamination could enter the connection will change. Therefore, we do not recommend detaching the fibers unnecessarily. Recalibration may be required if the fiber ends are scratched or contaminated with lubricants.

1.6. Mounting and Deployment

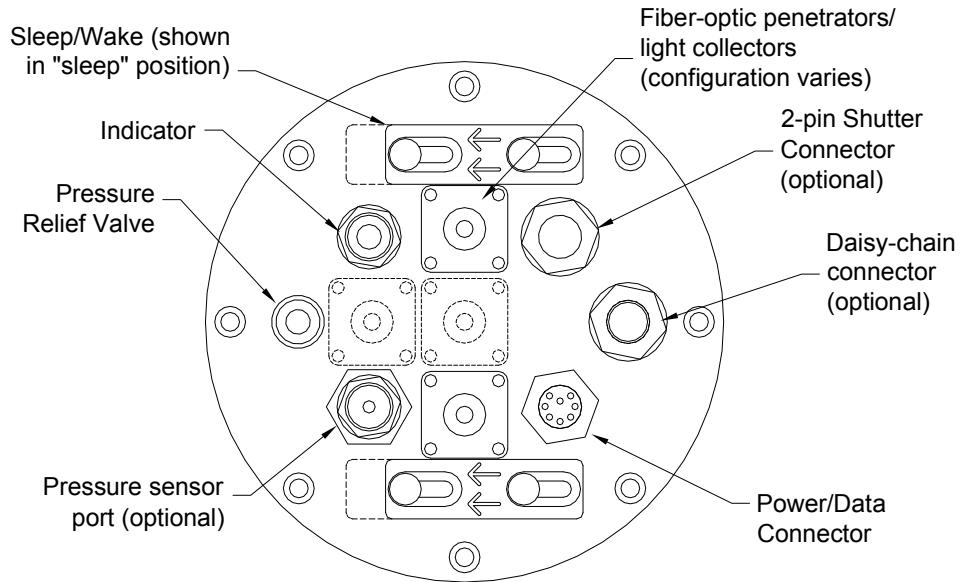
The metal pad-eye on Series 100 & 200 HydroRads is designed for convenience lifting and back-up tie-down only. It is not designed for profiling with the instrument. For profiling, the HydroRad should be secured in a HOBİ-supplied cage, or strapped to another support. A safety line should be connected from the HydroRad's metal pad-eye to the support cage.

1.7. Packing and Shipping

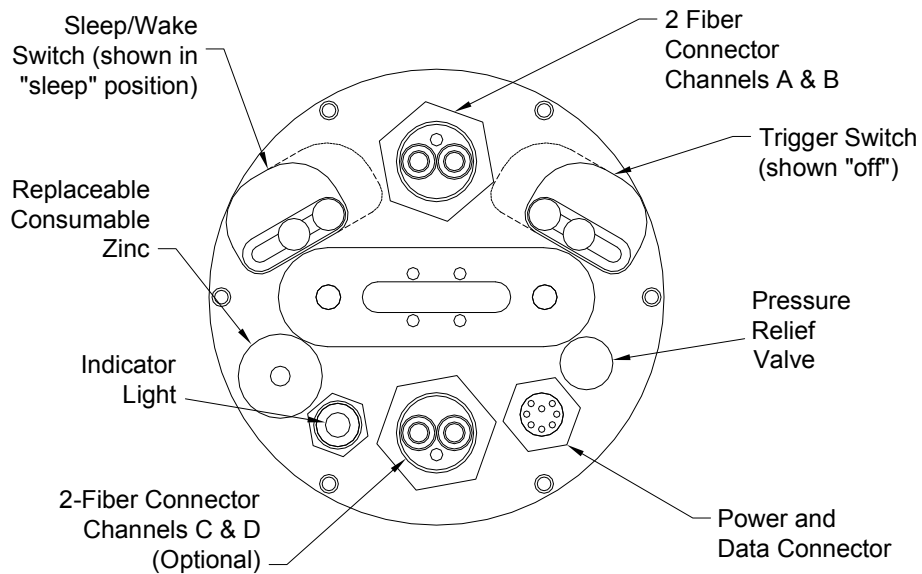
Use the shipping container and protective foam originally supplied with your HydroRad, and follow any packing instructions included with it. Be especially careful that the fiber optic cables are not coiled tightly and cannot be pinched by the instrument or case.

2. QUICK START

Series 300 HydroRad Layout



Series 200 HydroRad Layout



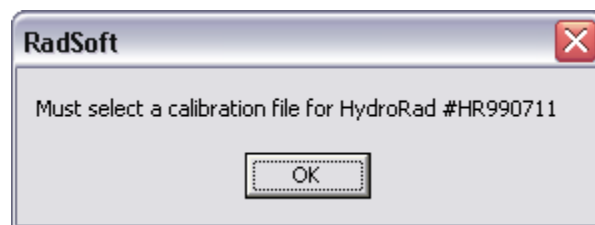
2.1. Basic Hookup

Requirements:

- Windows computer with an available serial (COM) port. If your computer has no COM ports, a USB-to-serial adapter can also be used.
- Installation program for RadSoft, either from a CD supplied with your instrument, or downloaded from www.hobilabs.com.
- Calibration file for your HydroRad, also on a CD supplied with your instrument. This is not strictly required, but is much faster than downloading the file from the instrument.
- HOBI-supplied Power/data interface (PDI) cable
- HOBI-supplied battery charger

Procedure:

- 1) Install RadSoft on your computer.
- 2) Connect the PDI cable to a serial port on your computer.
- 3) Connect the PDI cable to the 8-pin power and communications connector on the HydroRad.
- 4) Plug the cord from the battery charger transformer into the barrel connector on the data cable.
- 5) Plug the battery charger into a 120 VAC jack.
- 6) Start RadSoft, and select File...Connect. If you have a CD with the calibration file for this instrument, uncheck the Load calibration from Instrument option in the Connect to Instrument dialog box.
- 7) Click the Find port & baud rate button (or if you know the port and baud rate, you could also select the appropriate values and click the Connect button).
- 8) Press the Connect button. If this is the first time you have connected to the instrument and you unchecked the Load calibration from Instrument option above, you will see a message like:



- 9) When you click OK, you will be presented with the standard Windows dialog box for selecting a file. Navigate to the CD containing the calibration file for your instrument, and select it.

- 10) When the connection is complete and the calibration is loaded, the dialog box should disappear and an icon labeled with the serial number of your instrument should appear on the RadSoft Desktop:



- 11) If RadSoft cannot connect, see the following section for troubleshooting tips.
- 12) To do a quick check of the HydroRad's functions, expose all its collectors to continuous light, and select "Acquire One Sample" from the RadSoft File menu, which will collect one sample and display it in a graph on the screen. If the light levels on the collectors are low, a number of seconds may pass while the instrument seeks the correct integration time. Bright incandescent lights, or sunlight, are best for quick testing.
- 13) To set the HydroRad's time and date, select "Set Date/Time" from the instrument-specific menu.

2.2. Connection Troubleshooting

- 14) If there is no response from the instrument, try toggling the sleep/wake switch a few times. This should cause the indicator light to alternate between green to off.
- 15) If the indicator light turns red, the sample switch likely needs to be pushed out. Once the switch is pushed out, the red light should go out in a few seconds.
- 16) If RadSoft cannot connect, or if garbage characters are received during either of these operations, the baud rate likely needs to be adjusted on the PC.
- 17) If the indicator light is still off, the batteries may be either dead or at too low a level to operate the HydroRad's microcontroller properly. In this case, try charging the HydroRad for a while. In some cases, it may be necessary to use the battery-disconnect plug (section 5.3.4) momentarily after charging to revive the microcontroller.
- 18) If the HydroRad will not take a charge, be sure to check that the sample switch is pushed out. The battery charger cannot simultaneously charge the instrument and provide enough current for sampling.

3. OVERVIEW

HydroRad is a hyperspectral radiometer that can be configured with up to four channels (spectrometers). It includes a powerful programmable controller with extensive flash memory and the ability to collect and store data on an arbitrary schedule. When powered by its internal rechargeable batteries, HydroRad can operate autonomously for days or weeks. Logged data can be downloaded from HydroRad into any laptop or desktop computer with a standard serial communications port.

3.1. Spectrometers

Each HydroRad channel consists of its own miniature spectrometer. The spectrometer disperses incoming light onto a 2048-pixel Charge-Coupled Device (CCD) such that each pixel on the CCD corresponds to a specific optical wavelength. When exposed to light, the pixels accumulate charge that is proportional to the total energy at their respective wavelengths. Under the control of a microprocessor, the pixels accumulate charge for a certain integration time. At the end of the integration time, the charge from each pixel is read out and digitized, resulting in an array of numbers that represents the spectrum of the incoming light.

By varying the integration time of each spectrometer over a range of 20 ms to many seconds, HydroRad accommodates a very wide range of light levels. The user can set specific integration times for each channel, or allow HydroRad to automatically adjust the integration time according to the light levels it detects.

3.2. Optical Inputs and Collector Heads

HydroRad's optical inputs are fiber optic connectors, to which various light collectors can be connected through fiber cables. HOBI Labs supplies irradiance and radiance heads for measurement of the most common radiometric quantities, but users may also connect inputs from other sources.

3.3. Control Electronics

A miniature computer controls all aspects of HydroRad's operation. Its primary functions are to:

- control power to the spectrometers and other subsystems,
- generate timing signals for the spectrometers,
- digitize the spectrometer outputs,
- calibrate and filter data,
- store data in flash memory,
- accept configuration instructions and commands from the user,
- execute commands stored in files,

- sleep and wake according to programmed schedules,
- download data from flash memory.

The user interacts with the controller by sending commands and receiving replies over an RS-232 serial link. A large variety of commands let the user configure and control HydroRad for many different situations. HydroRad can also run sequences of commands stored as files in the flash memory, in the manner of MS-DOS batch files. HydroRad command files can include assigned times at which specific commands are to be executed, allowing users to set up arbitrary data logging schedules.

When not actively collecting data, the controller can be instructed to go into a low-power sleep mode to preserve power in the batteries. This, combined with scheduled command files, allows HydroRad to operate autonomously for extended periods while powered by its internal batteries.

3.4. Data Logging and Processing

The flash memory in HydroRad is configured as a virtual hard disk, with a standard capacity of 48 Megabytes and optional capacities from 15 up to 256 Megabytes. The flash disk supports a file system like that found on desktop computers, which allows the user to manage files using familiar commands like “erase”, “copy”, “dir” (for directory) and “ren” (for rename). RadSoft extends the user interface to the Windows world, allowing the user to manipulate files with a familiar Explorer-like interface.

HydroRad offers various options for processing spectra before storing them. It can store data in raw, partially calibrated, or fully calibrated form, average multiple spectra, and apply spectral filtering.

4. HYDRORAD CONFIGURATIONS

The HydroRad family comprises a range of configurations including different numbers of spectrometers, spectrometer setups, and collector configurations.

4.1. Base Models

The number in the HydroRad model indicates how many channels (spectrometers) it contains. For each channel, the default configurations include one collector mounted on a fiber optic cable. Collectors may also be “embedded,” that is mounted directly on the HydroRad housing with no external fiber optic cable. This is most commonly used for a surface-mounted units that measure irradiance above the water surface, but also provides a convenient all-in-one package for other applications.

Since irradiance collectors pick up light from all angles, they must be mounted on a flat surface. On the HydroRad, this means the end cap on the opposite end from the connector endcap.

HydroRad Model	Total Channels (spectrometers)	Fiber Optic Collectors	Embedded Collectors
-1	1	1	-
-E1	1	-	1
-ES1	1	-	1 (with anti-fouling shutter)
-2	2	2	-
-E2	2	-	2 (one on each end)
-3	3	3	-
-4	4	4	-

Type	Diameter	Length	Dry weight	Submerged weight
HR-1 and -2	13.3 cm (5.25")	30.5 cm (12")	3.3 kg	0.5 kg
HR-3 and -4	13.3 cm (5.25")	46.6 cm (18.3")	5.3 kg	1 kg



HydroRad-E1 with a plane irradiance collector and HydroRad-2 with one plane irradiance and one radiance collector.



HydroRad-4 with 2 plane irradiance and 2 scalar irradiance collectors on long cables



Connector endcap of a HydroRad-3



E and L collectors



HydroRad-E2 Endcap with embedded Radiance Collector

Note that any cable attached to the electrical connector must be kept out of the field of view of the collector (15° or less).

4.2. Spectrometer Configurations and Performance.

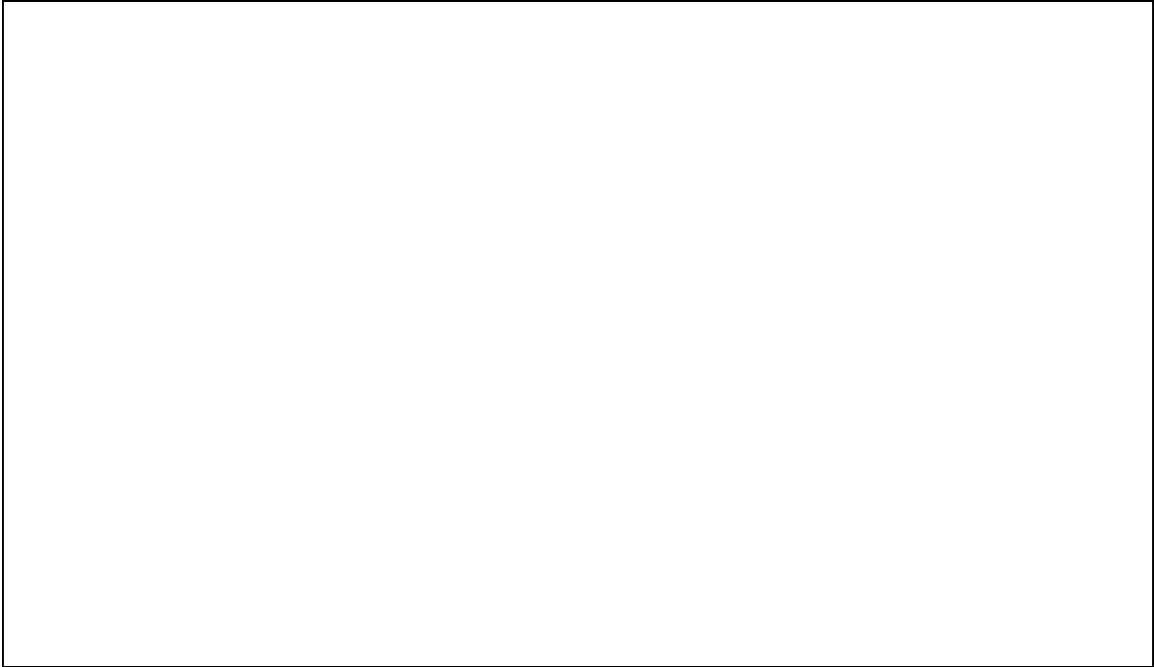
The spectrometers within each HydroRad can also be configured with various options. The key variable components in the system are the diffraction grating, which determines the spectral sensitivity curve, and the entrance slit, which offers a tradeoff between sensitivity and spectral resolution.

Most HydroRads are configured with 50 micron slits, which provide spectral resolution of less than 3nm FWHM and good sensitivity (see the discussion of sensitivity below). If the utmost sensitivity is required, 100 or 200 micron slits are also available, but these will degrade the spectral resolution. Depending on the collector configuration, fiber optics larger than our standard 200 micron may be available to increase the sensitivity also. If resolution is more important than sensitivity, smaller slits can be used.

The diffraction grating is the most important variable in determining system spectral response. (The sensitivity of the CCD detector is also crucial, but cannot be changed.) Most HydroRads are supplied with a standard grating that provides a usable spectral range of approximately 350 to 850 nm. The spectrometer response falls gradually at both ends of the spectrum, so there are no distinct cutoff wavelengths. The effective spectral range of the system depends on the application and the ultimate sensitivity, signal-to-noise ratio, and dynamic range required. To understand this better, see the following plot.

The plot shows the complete system response for a spectrometer with a planar irradiance collector, 2-meter 200-micron-core fiber optic cable, and 50-micron entrance slit. The upper curve is the irradiances at which the spectrometer saturates, when operating at its minimum integration time. The lower curve show the effective noise irradiance, within 10nm bandwidth averaging, when the integration time is set to 20 seconds. The curves have the same shape, indicating that the noise level is a constant fraction of the saturation response, across the spectrum. The curves differ from each other by a factor of about 2,000,000, which is the total system dynamic range for a given wavelength.

Within a single spectrum with 10nm bandwidth averaging, the S/N is typically 1000:1 for a full-scale signal and the raw dynamic range (ratio of full-scale reading to RMS dark noise) is greater than 2000:1. The dynamic range is higher than the S/N because the absolute noise actually decreases at lower signals. The noise level can be decreased further with additional bandwidth averaging, averaging of multiple spectra, or both.



**Saturation radiances and effective dark noise irradiance of standard configuration,
set for maximum sensitivity.**

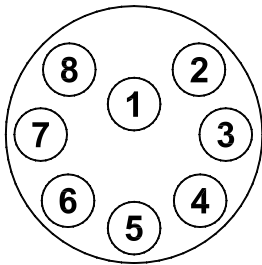
5. POWER AND DATA CONNECTIONS

HydroRad can be powered from three sources:

- 1) External 10V to 15V supply,
- 2) Internal battery,
- 3) External 18V to 24V battery charger

Any combination of these sources may be safely connected simultaneously (**NOTE:** voltages above 15V can **only** safely be applied to the battery charging input). Power will be drawn from the source with the highest voltage. Nominal power draw at 12V input is 50 mA plus 70 mA per channel during sampling, and 1 mA during low-power sleep. Note that if the battery charger is connected as the only power source, operating HydroRad will reduce the charging current to the battery and increase the needed charging time.

The HydroRad communicates via RS-232 through a standard computer serial port. Power and data lines are brought out on a SubConn MCBH8M connector (mate: MCIL8F), with pins assigned as shown below.



PIN	FUNCTION
1	Supply voltage (10 to 15 VDC)
2	Common
3	RS232 Instrument Receive
4	RS232 Instrument Transmit
5	Battery charging input (18 to 24 VDC)
6	Output to Shutter -/+
7	Output to Shutter +/-
8	Short to Common to Disable Battery

The supplied cable splits into a DB9 for communication, a “barrel” connector for the battery charger, and a pigtail for an external DC supply.

5.1. Optional Shutter Connector

HydroRads may also be configured with a separate MCBH2F connector to drive shutters, in which case Pins 1 and 2 are wired to the signals that would otherwise go to pins 6 and 7, respectively, on the 8-pin connector.

5.2. Optional Daisy-chain Connector

An MCBH8F connector may be installed, through which two HydroRads may be connected to together such that they function as a unit. The most common application for this is to connect an instrument measuring irradiance on the surface with one measuring underwater. Also see the DAISYCHAIN command in section 8.2.4.

5.3. Internal Battery

The standard HydroRad configuration includes internal rechargeable batteries. Note however that in cases where the instrument will operate for long periods (more than a few weeks) without charging the batteries, it is preferable to disable them or leave them out entirely. For this reason some HydroRads may not contain batteries.

5.3.1. Battery Capacity

The capacity of the battery depends on the temperature at which it is charged, stored, and discharged. Charging and storage at temperatures of 20 C or less improve capacity. On the other hand, low temperatures during discharge lower the realized capacity. Peak capacity for a battery charged and discharged at room temperature is 12 hours of continuous operation with an HR-2, and 8 hours with a HR-4.

In response to the sleep/wake switch being turned to “sleep”, or the SLEEP software command, the HydroRad will enter a low-power sleep state during which its current drain is reduced to about 1 mA. In this state fully charged batteries will last about 2 months. Hourly sampling schemes can typically last about 1 month.

Capacity decreases slowly as the battery ages. The capacity loss depends greatly on charging conditions, but is typically less than 10% after 200 charge/discharge cycles, and 20% after 500 cycles.

5.3.2. Battery Voltage and State of Charge

To read current value of the battery voltage whenever communication is established with the sensor, enter the BATT command. This will display the current voltage and the battery charging current. The battery voltage gives a rough indication of how much charge remains. When the battery voltage falls below 11 V, indicating it is virtually completely discharged, the HydroRad should not be used in battery-mode operation. HydroRad will go into its low-power sleep mode whenever the voltage falls below this threshold.

5.3.3. Charging

HydroRads with batteries installed include constant-current chargers that recharge the battery in a maximum of 15 hours. Any replacement charger used for a HydroRad should put out between 18 and 27 volts DC; chargers that put out less than 18 volts will not be able to fully charge the HydroRad. The actual charging time required after a partial discharge is about 40% longer than the full power operating time for a HR-4, and about equal to the full power operating time for a HR-2. Charging continues at the same rate as long as the charger is plugged in.

If the HydroRad is operating with the battery charger plugged in, note that the current going to the batteries will be reduced and the charging time will increase. For a HR-3 or HR-4 continuously sampling, the batteries can drain, even with the charger plugged in. For fastest charging, either put HydroRad to sleep, or provide an external power supply whose voltage is higher than the battery voltage. A 13.8V power supply is recommended for this situation.

NOTE: to protect against disruptive transients, connect the output of the charger to the instrument before plugging the charger into an AC outlet.

While the battery tolerates indefinite periods of charging, repeated, prolonged charges can eventually degrade battery capacity. For best battery life we recommend that you charge, on average, not more than 3 times the time that the sensor is operated from the battery (not including “sleep” time).

5.3.4. Battery Disable

The battery can be electronically disconnected from the HydroRad circuitry by shorting pins 2 and 8 of the bulkhead connector together. A special dummy plug, distinguished from the normal dummy by a colored band, is provided for momentarily disconnecting the battery to reset the instrument in case of a software fault. The special dummy plug can also be used to save battery charge during extended storage.

In some cases, it may be desirable to permanently disable the battery if HydroRad is to be externally powered for several months on a mooring. This will require a communication cable that shorts pins 2 and 8. This will protect the instrument firmware from hanging if the batteries drain to a very low voltage level due to current leakage, and the external voltage is accidentally cycled. However, the mooring controller will then have to reset the HydroRad’s clock. In most cases, it is preferable to leave the batteries connected so that the HydroRad’s clock is maintained during mooring power outages.

Note that like the hard disk in a computer, HydroRad’s flash “disk” can be corrupted if power is removed while it is updating its directory. Therefore, do not disable the battery while HydroRad is storing data or performing file operations. If you remove power when the indicator light is green or off, there is no risk of losing data.

Disabling the battery will cause HydroRad’s real-time clock to reset, and will also reset any parameters that were changed without being saved to flash by the SAVEPARAMS command.

6. COMMUNICATIONS

HydroRad communicates through a standard RS-232 serial connection to any computer serial port. Any common terminal emulator program can be used, but RadSoft is preferred, as it has many features tailored specifically for the HydroRad.

6.1. COMMUNICATION PARAMETERS

HydroRad's serial protocol is 8 bits, no parity, 1 stop bit, and no flow control. Only the transmit, receive and ground lines are connected between HydroRad and the computer.

6.2. BAUD RATES

The default communication rate is 9600 baud (some systems are shipped however with the baud rate set to 57600 as described in section 6.3). 9600 baud is robust and adequate for routine communication with the instrument, but when downloading large amounts of data it is desirable to increase the rate by using the BAUD command (see 8.2.2). Standard baud rates from 300 to 230,400 baud are supported. Note that most PC serial ports do not support 230,400 baud, and some may have trouble with even lower rates. Also note that high baud rates may not work over long cables. If you plan to use high baud rates and long cables in the field, test your system first in the lab!

Changes made with BAUD remain in effect until one of the following events causes HydroRad to return to its default baud rate:

- execution of the RESET command,
- exiting the HydroRad operating program via the QUIT, PicoDOS or TOM8 command,
- interruption of power by disabling the battery (see section 5.3.4)

6.3. CHANGING DEFAULT BAUD RATE


You can change the default baud rate by creating an AUTOEXEC.BAT file containing a BAUD command on the flash disk. This file will be executed each time the HydroRad operating program starts, resets or quits to PicoDOS (quitting to TOM8 always returns the baud rate to 9600). NOTE: before setting a high baud rate as the default, test it with the BAUD command. If you set the default to a rate that isn't supported well by your computer or cabling, it may be very difficult return to a usable rate!

To create a file setting the baud rate to 57600 (note that this process will erase any existing AUTOEXEC.BAT file):

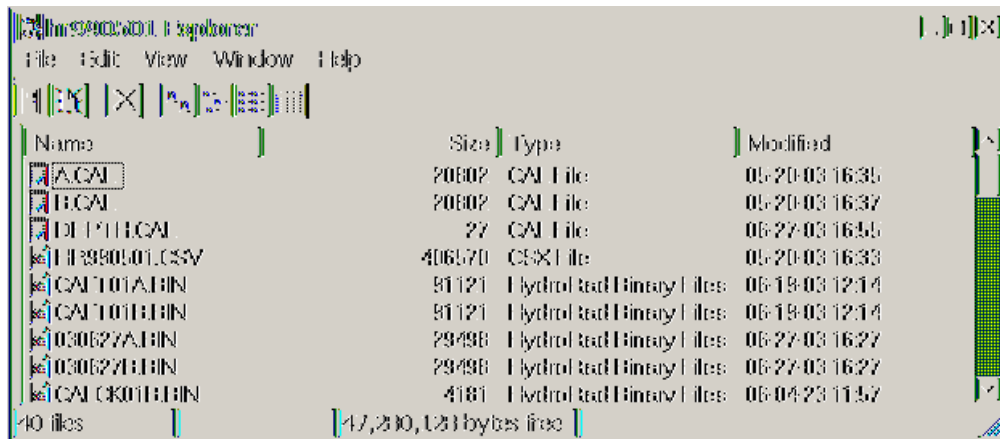
- 1) At the HydroRad prompt, type `CAPTURE AUTOEXEC.BAT<enter>`.
- 2) At the `Capture>` prompt, type `BAUD 57600 /Q <enter> <control-z>`.

You can delete AUTOEXEC.BAT or capture a new one at any time to change the default rate. If you want the new AUTOEXEC.BAT (or lack of one) to take effect immediately, type RESET<enter> at the HydroRad prompt.

6.4. File Transfers using the RadSoft Device Explorer

From the RadSoft Desktop, if there is more than one device, click on that device to select it, and Select Device Explorer () from the File menu there is only one device, then it will be automatically selected.

After a pause (during which lines will scroll in the Terminal window), a window like the following will appear:



After the directory is loaded, select the data sets or casts you wish to retrieve. Right click on the selected files to bring up a menu, which will allow you to either get the files from the instrument and save them to disk, or to open them directly in RadSoft. If you choose to get the files from the instrument, then you will be prompted for a directory into which to save the files.

You may also simply drag the selected files from the RadSoft Explorer into a Microsoft Windows™ folder, or onto the Windows™ Desktop.

Depending on the quantity of data and baud rate, downloading may take some time. Status messages and a graphical indicator will show the download progress.

You can select arbitrary groups of data sets for downloading. To select a contiguous group of casts, click on the first item in the group, then shift-click on the last item; or hold down the shift key while using the arrow keys. To select or unselect non-contiguous casts, control-click on them; or hold down the control key while using the arrow keys to move through the directory, and press the space bar to select or unselect casts.

Text files can also be sent to the HydroRad though the device explorer. Either drag the text files into the device explorer window, or select "Send File To Instrument" from the Device Explorer's File menu.

7. EXTERNAL SWITCHES

HydroRads include magnetically coupled switches that can be used to control the sensor without connecting to a computer. See the figures below for the location of these switches.

7.1. SLEEP/WAKE SWITCH

One switch acts as an on/off power switch, although it cannot actually turn off power to the sensor. When switched from wake to sleep, it signals HydroRad to go into an indefinite sleep (as if it had received the SLEEP command). When switched from sleep to wake it wakes the sensor from sleep. Because the switch only signals the sensor to sleep or wake, it is possible to wake HydroRad with serial communication from a computer, even if the power switch is in the off position. It is likewise possible to command the sensor to sleep even if the switch is on. Switching the power switch to off while the sensor is asleep will have no effect. Note that the sleep and wake functions only work while the HydroRad operating program is running, and will not work when running PicoDOS.

7.2. TRIGGER SWITCH

PLEASE NOTE: OPERATION OF THE TRIGGER SWITCH WAS SIGNIFICANTLY DIFFERENT IN FIRMWARE VERSIONS PRIOR TO 1.27.

The second switch triggers data collection. If the sensor is awake, the trigger switch signals the HydroRad firmware to execute a command file `TRIGGER.CMD`. This allows the user to specify an arbitrary response to the trigger switch. If no `TRIGGER.CMD` file is present on the flash card, the `START` command will be executed, which periodically runs the `LOG` command with the default parameters set in the `LOGPARAMS` command.

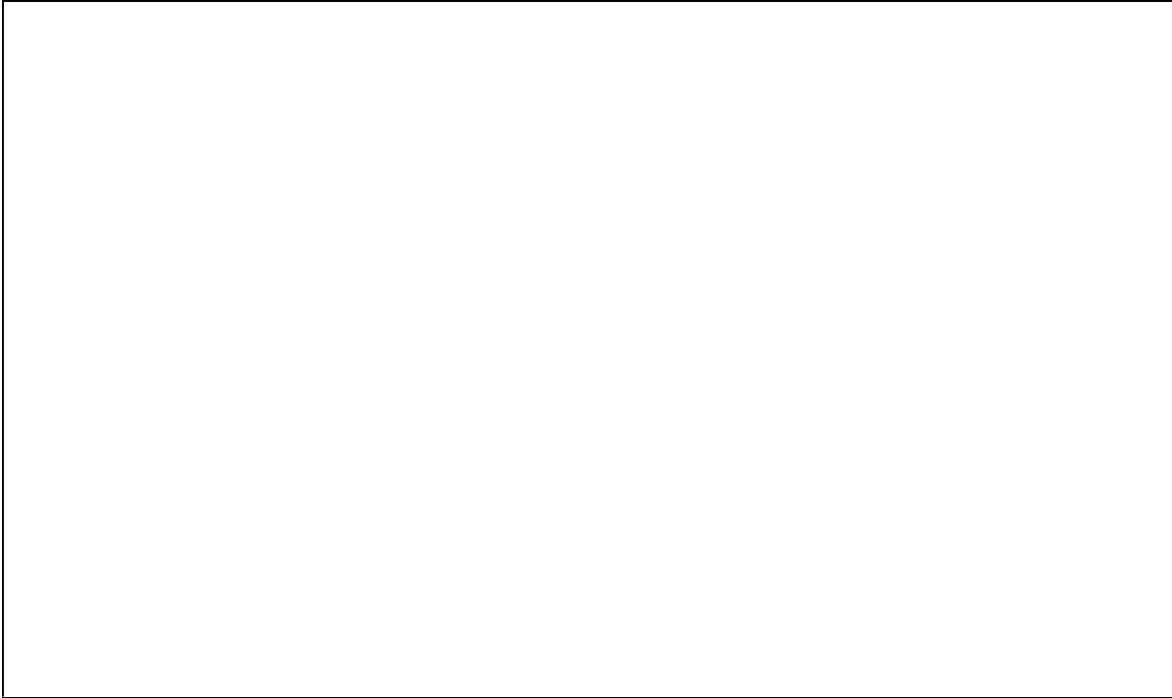
Prior to version 1.27, if the trigger switch were operated momentarily, `LOGAUTO` or `TRIGGER.CMD` would be executed once. Switching off the switch while a command was in progress would not interrupt the command. In versions 1.27 and beyond, switching off the trigger switch now cancels any running commands or data collection.

Also, prior to version 1.27, leaving the trigger switch on would cause the `trigger.cmd` file to execute repeatedly. In versions 1.27 and beyond, the `trigger.cmd` file is executed only once (unless it is a timed command file, in which case it repeats like a timed command file). To cause a command in the `trigger.cmd` file to be repeated, use the syntax "`START Command...`" within the `trigger.cmd` file. If several commands must be repeated, use the syntax "`START repeat.cmd`", where `repeat.cmd` is a second command file containing the commands to be repeated.

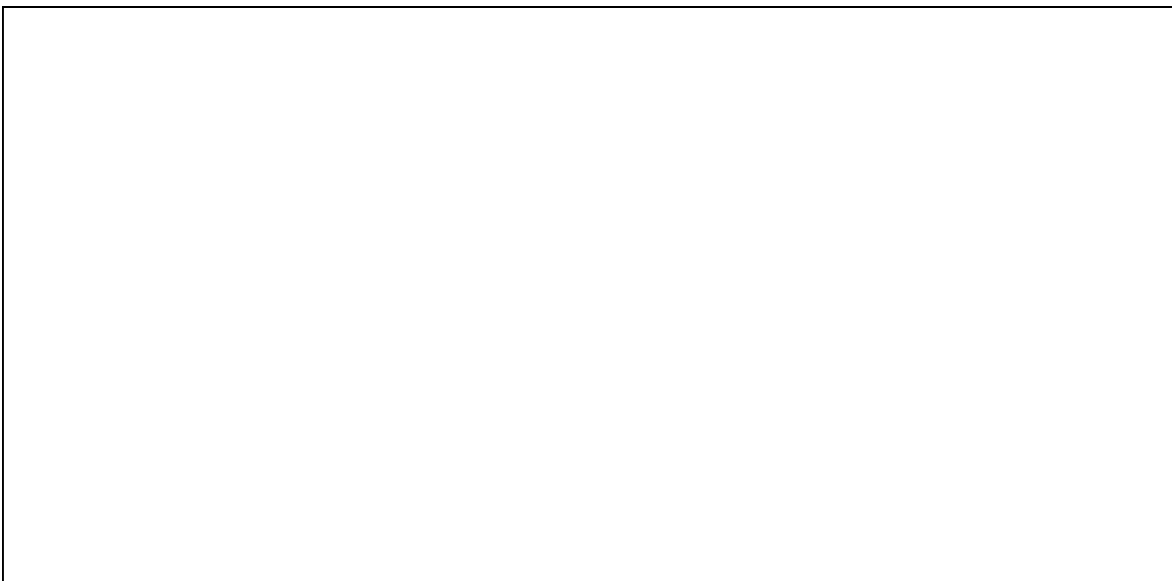
The trigger switch has no effect if the sensor is asleep. However, if the trigger switch is turned on while the sensor is asleep, it will cause a trigger event when the

instrument wakes. Also, if collection was started with the trigger switch in the "on" position, and the trigger switch is shut off while the instrument is asleep, then collection will halt when the instrument wakes.

Series 300 HydroRad Switch Locations



Series 200 HydroRad Switch Locations



8. COMMANDS

HydroRad is controlled and configured with text commands received via its serial port. Its commands are designed to be human-readable and reply with informative messages, although they could also be generated from a user-programmed computer or logger. All commands can also be executed from files stored in HydroRad's flash memory (see section 9).

8.1. COMMAND CONVENTIONS

For clarity in this document commands are shown in upper case, but they are not case-sensitive.

Some commands accept arguments, which are separated from the base command, and from each other, by commas or spaces. Arguments may be individually omitted, in which case they will have no effect. For example, if a command accepts three arguments, in the form `COMMAND,arg1,arg2,arg3` (or `COMMAND arg1 arg2 arg3`), you may adjust only `arg3` by entering `COMMAND,,,arg3`.

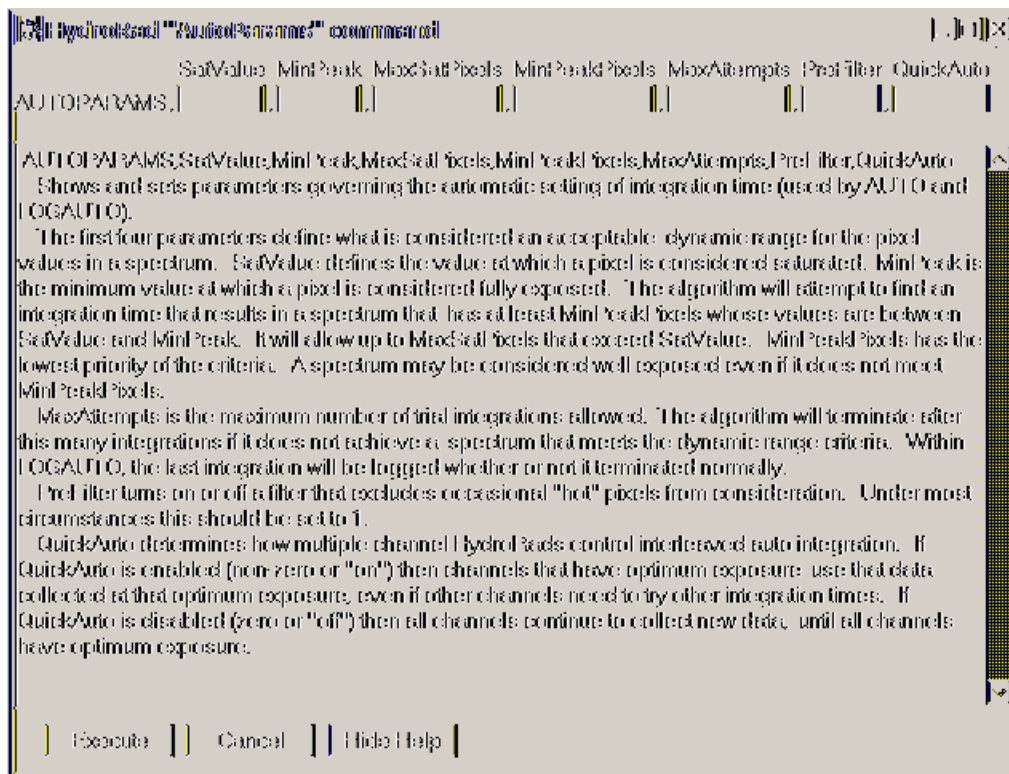
In firmware versions 1.17 and later, combinations of spaces and/or a single comma are treated as a single delimiter. In previous firmware versions, every space or comma was treated as a separate delimiter.

Most commands reply with the settings of relevant parameters, or other status information.

8.1.1. Sending Commands from RadSoft

If a HydroRad is connected through RadSoft, then any of the commands listed in this manual can be sent with the correct syntax (i.e. the correct number of commas) through the RadSoft command window for that command. Commands may also be typed directly into the RadSoft terminal window.

Once a HydroRad is connected through RadSoft, its device-specific menu will be enabled (that is the menu with the HydroRad's serial number as its title). Within the device specific menu, there are several sub-menus that reflect the sections that follow in this manual: "Direct Config Commands", "Direct General Commands", "Direct Data Commands", etc. Within each of those menus are several commands. Selecting a command launches a command dialog that displays the command name, and includes an edit box of each field of the command. Help information is also displayed to assist the user with filling in the command. For example, if "AutoParams" were selected from "Direct Config Commands", the following dialog would appear:



Pressing "Execute" after filling in the desired fields sends the correctly formatted command to the HydroRad.

8.1.2. HydroRad Reserved Words

The words “on”, “open”, or “yes” are all defined as equal to 1 in command arguments that expect logical values, and may be used in place of the value 1. In place of the value zero in command arguments, the words “off”, “close”, or “no” may be used. These words are not case sensitive.

8.1.3. HydroRad Channel Numbering

Commands that refer to channels will accept either a channel number or letter as an argument. Thus, the first channel can be referred to as either “1”, “a”, or “A”.

8.2. CONFIGURATION COMMANDS

8.2.1. AUTOPARAMS SatValue MinPeak MaxSatPixels MinPeakPixels MaxAttempts PreFilter

Shows and sets parameters governing the automatic setting of integration time (used by AUTO, ACQUIRE, LOG, and LOGAUTO).

The first four parameters define what is considered an acceptable dynamic range for the pixel values in a spectrum. *SatValue* defines the value at which a pixel is considered saturated. *MinPeak* is the minimum value at which a pixel is considered fully exposed. The range for both of these values is 2000 to 32760.

Please note that higher *SatValue* and *MinPeak* settings will result in more fully saturated, potentially more accurate readings when used with the “**LogAuto**,” “**Log Auto**” or “**Acquire Auto**” command sequences. However, when using the **Log** or **Acquire** commands in the default speed-auto mode, higher settings will lead to more over-exposed samples, and less usable data. In fact, if light levels are changing rapidly, lower *SatValue* and *MinPeak* settings will result in fewer over-exposed measurements, and more usable data in speed-auto mode.

The algorithm will attempt to find an integration time that results in a spectrum that has at least *MinPeakPixels* whose values are between *SatValue* and *MinPeak*. It will allow up to *MaxSatPixels* that exceed *SatValue*. *MinPeakPixels* has the lowest priority of the criteria. A spectrum may be considered well exposed even if it does not meet *MinPeakPixels*.

MaxAttempts is the maximum number of trial integrations allowed. The algorithm will terminate after this many integrations if it does not achieve a spectrum that meets the dynamic range criteria. Within LOGAUTO, the last integration will be logged whether or not it terminated normally.

PreFilter sets the width of a filter that excludes occasional "hot" pixels from consideration. Under most circumstances this should be set to 3.

The *QuickAuto* parameter existed in firmware versions 1.25 through 1.32, but has been eliminated.

8.2.2. AUXSETUP

New in firmware 1.26.

Shows the configuration of the NMEA-output auxiliary device, if one is attached.

8.2.3. BAUD newrate [/Q]

Change to a new baud rate. Without the /Q flag, BAUD replies:

Changing to XXXX BAUD.

Hit <return> when ready...

and waits until it receives another character (not necessarily <return>). With the /Q flag (which stands for “quiet”), the baud rate will immediately change without any further input. **There must be a space between the newrate parameter and the /Q flag, or the /Q will be ignored.**

Standard baud rates from 300 to 230,400 baud are supported. Note that most PC serial ports do not support 230,400 baud, and some may have trouble with even lower rates. Also note that high baud rates may not work over long cables. If you plan to use high baud rates and long cables in the field, test your system first in the lab!

The baud rate you set remains in effect until changed by another BAUD command, you exit the HydroRad operating software, or the HydroRad is reset by removal of power or the RESET command. See also sections 6.2 and 6.3.

8.2.4. DAISYCHAIN BaseChan MaxChan

New in firmware 1.25.

For daisy-chained HydroRads, this command controls the master/slave relationships and the numbering of channels. For non-daisy chained HydroRads, *BaseChan* is set to channel "A", and *MaxChan* is set to the maximum available channel on the HydroRad ("B" for a HydroRad-2, for example).

Master HydroRads (with a slave HydroRad) have *MaxChan* values greater than the number of local spectrometers, to account for additional slave spectrometers. Slave HydroRads (to be attached to a master HydroRad) have *BaseChan* values that are one greater than the number of channels on the master.

So, if a HydroRad-1 and a HydroRad-2 were to be daisy chained together, one would enter on the master unit (HydroRad-1):

DaisyChain, A, C

And on the slave unit (HydroRad-2)

DaisyChain, B, C

Once this is done, the slave unit will start saving logged data to files with the "B" and "C" suffixes instead of "A" and "B".

Also, slave units normally have ECHO set to off, to streamline the master-slave communications. Setting slave units' echo setting to "on" can have unpredictable effects. See the ECHO command for more information.

8.2.5. DEPTHCAL Offset ScaleFactor

DEPTHCAL sets the coefficients used to calculate calibrated depth readings from the HydroRad pressure sensor. *Offset* is the raw reading at atmospheric pressure. *ScaleFactor* is the coefficient to convert digital counts to equivalent meters of depth in water. Values entered with DEPTHCAL take effect immediately, and are saved in the file `DEPTH.CAL` so they will remain in effect until changed with another DEPTHCAL command.

8.2.6. DATE mm/dd/yy hh:mm:ss

Identical to the TIME command. Sets the date and/or time of the real-time clock. The command will accept partial dates (for example 3/1 sets the month to 3 and the day to 1 without affecting the year) and times (for example 13:24 sets the hour and minute without affecting the seconds). Years may be entered with 2 or 4 digits.

8.2.7. ECHO state or ECHO string

State specifies whether characters sent to HydroRad's serial port are automatically echoed. If state is "on" (1) then echo is turned on, if state is "off" (zero) then echo is turned off. The default is on. With echo off, characters you type will not appear in your terminal software.

If a string follows the echo command, the string will be echoed to the command line. Be careful, because if the first word of the string is one of the HydroRad reserved words: “on”, “open”, “yes”, “off”, “close”, “no”, the value of the reserved word will be used as if you were specifying a *State*, and the rest of the string will be ignored.

8.2.8. FILTPARAMS FirstPixel LastPixel PixelIncrement FilterSpec FilterSize

Before a spectrum is saved by one of the logging commands (LOG, LOGFIXED, LOGRANGE, LOGAUTO), or displayed by the FILT command, it is filtered by convolution with a filter specified by the parameter *FilterSpec*. Then a subset of pixels, defined by the *FirstPixel*, *LastPixel* and *PixelIncrement* parameters is selected from the filtered spectrum. IMPORTANT: If you set *PixelIncrement* to a value other than 1, you should set the *processing* parameter of LOGPARAMS to a value of 1 or higher. See section 10.2 for information about how filtering and selecting pixels can affect the quality of your data.

If *PixelIncrement* is a positive number, then *FirstPixel*, *LastPixel*, and *PixelIncrement* will correspond to physical pixels. If *PixelIncrement* is a negative number, and a calibration has been imported into the HydroRad (see ImportCal) then *FirstPixel* and *LastPixel*, and $|\text{PixelIncrement}|$ will be 10ths of nanometers. (New in firmware version 1.29)

FilterSpec can be 0, 1, or 2. A value of 0 (zero) or "off" specifies no filtering. A value of 1 specifies boxcar averaging, in which case each pixel in the output spectrum will be the result of an equally-weighted average of the number of pixels or wavelength range specified by *FilterSize* (rounded up to an odd integer if necessary). A value of 2 specifies Gaussian averaging, where each pixel in the output spectrum will be the result of a normal distribution-weighted average, with a full width at half max (FWHM) equal to the number of pixels or wavelength range specified by *FilterSize*.

Prior to firmware version 1.29, *FilterSpec* could be a file name. This is no longer supported.

If *FilterSize* is a positive integer, then it will correspond to that fixed number of pixels. If *FilterSize* is a negative integer, then the filter width will be that many 10ths of nm wide. So, a *FilterSize* of 5 specifies a 5 pixel-wide filter. A filter size of -15 specifies a 1.5 nm wide filter.

Whether or not arguments are specified, FILTPARAMS displays the parameters and the currently loaded filter coefficients, if any.

8.2.9. ID

Displays the factory-set model, serial number, and configuration information about the HydroRad.

8.2.10. IMPORTCAL Filename

Given a file containing properly formatted calibration data for one or more channels, translates the file into a binary format for future rapid loading. The resulting binary files are named A.CAL for channel 1, B.CAL, etc.

If the DAISYCHAIN command is used, IMPORTCAL does NOT have to be repeated.

8.2.11. INTPARAMS MinTime MaxTime WarmupTime AutoPowerDown Channels

Shows and sets parameters governing integration. *MinTime* is the minimum integration time, in milliseconds, used in auto-integration commands such as AUTO, LOGAUTO, and START. This is typically set to the electronic limit of 20 ms. *MaxTime* is the maximum integration time, in milliseconds, used in auto-integration commands such as AUTO, LOGAUTO, and START. Practical values of *MaxTime* range from 2000 to 30000 milliseconds, although it can be set higher.

WarmupTime is the number of seconds HydroRad will wait before collecting spectra after power is first applied to the spectrometers.

AutoPowerDown can be either zero, or a number greater than zero. If it is nonzero, then power to the spectrometers will be turned off if they are idle for more than 2 seconds plus *WarmupTime*.

Channels is a string of digits or letters specifying from which channels data will be collected. For example, 13 or AC indicates that channels 1 and 3 are enabled. Note that HydroRads may be equipped with different numbers of channels. Normally all installed channels should be enabled.

8.2.12. LAMBDA Channel Pixel

Given a channel and pixel (ranging from 0 to 2047), displays the wavelength (in nm) corresponding to the pixel. Channel may be specified with a letter, a number, and asterisk "*" for all channels. If no channel is specified, the current CHAN setting is used.

8.2.13. LOADFILT FileName

Eliminated in firmware version 1.29

8.2.14. LOADPARAMS FileName

LOADPARAMS restores parameters saved in a file by SAVEPARAMS. If no *FileName* is specified, it loads HYDRORAD.INI.

8.2.15. LOGPARAMS SampleInterval SampleDuration Processing OutputFormat OutputDestination

SampleInterval and *SampleDuration*, both in seconds, are used for continuous periodic collection as initiated by the START command or trigger switch. They are not relevant to collection scheduled by a command file, unless that file contains a START command.

IMPORTANT: See section 10.2 for information about how the *Processing* parameter can interact with other parameters to affect the quality of your data.

The *Processing* parameter controls which calibration steps are applied to data before they are filtered and saved:

- 0 - raw, unprocessed "counts" are returned
- 1 - "weak pixel" adjustments are performed
- 2 - dark-current is calculated and subtracted from the counts
- 3 - counts are divided by the integration time
- 4 - engineering units are returned (full calibration)

OutputFormat controls whether spectra generated by the logging commands (LOG, LOGFIXED, LOGRANGE and LOGAUTO) are in ASCII or binary format:

-2: spectra saved in binary with CRC checksum and host reply (.BIN extension on files). If the output is to the console, the data is followed by a "?". Within 2 seconds, the host must respond with an acknowledgment of good data "Y", or an indicator of bad data "X". If bad data is indicated, or no response is received in 2 seconds, then the data is re-sent, up to 10 times per channel.

-1: spectra saved in binary with CRC checksum (.BIN extension on files)

0: spectra saved in binary (.BIN extension on files)

1: spectra saved in text (.ASC extension on files)

2: for backwards compatibility, sets *OutputFormat* to 0 and sets *OutputDestination* to 2.)

3: for backwards compatibility, sets *OutputFormat* to 1 and sets *OutputDestination* to 2.)

OutputDestination selects where data are output:

0: multiple files (Channel letter appended to file name)

1: single file

2: host console

3: host console + multiple files

4: host console + single files

8.2.16. PARAMS

Displays all the settable parameters. Similar to typing LOGPARAMS, FILTPARAMS, AUTOPARAMS and INTPARAMS in succession, except that PARAMS can not change any parameter values. This is handy if you forget which parameters are available, or which command to use for a particular setting. See also SAVEPARAMS, LOADPARAMS.

8.2.17. **PIXEL Channel Wavelength**

Given a channel and wavelength, displays the pixel most closely corresponding to the wavelength. *Channel* may be specified with a letter, a number, or an asterisk "*" to specify all channels. If no channel is specified, the current CHAN setting is used.

8.2.18. **SAVEPARAMS Filename**

SAVEPARAMS stores all the parameters set with LOGPARAMS, INTPARAMS, AUTOPARAMS and FILTPARAMS in a file with the given *Filename*. If no *Filename* is specified, they will be stored in HYDRORAD.INI, which is automatically loaded whenever HydroRad starts up.

8.2.19. **SET VariableName Value**

Sets the value of environment variable *VariableName* to *Value*, which can be a string or numeric expression. Use %*VariableName*% to insert the value into other expressions.

8.2.20. **SHOWCAL Channel FirstPixel LastPixel**

Displays, in ASCII, the currently loaded calibration data for a given channel, from the *FirstPixel* to the *LastPixel*. Header information displayed includes HydroRad Serial Number, Channel name, Units, and Scale. For each pixel between *FirstPixel* and *LastPixel*, the constants displayed include "F," which determines the dark current calibration function to use, "C," which is the floating point constant used in the dark current calibration, and "Epsilon," which the count rate is divided by to obtain engineering units. *Channel* may be entered as a letter, a number, or an asterisk "*" to indicate all channels.

8.2.21. **TIME mm/dd/yy hh:mm:ss**

Identical to the DATE command. Sets the date and/or time of the real-time clock. The command will accept partial dates (for example 3/1 sets the month to 3 and the day to 1 without affecting the year) and times (for example 13:24 sets the hour and minute without affecting the seconds). Years may be entered with 2 or 4 digits.

8.2.22. **TXDELAY Delay**

Sets the minimum time (in milliseconds) by which HydroRad delays its responses to commands, in case the system with which it is communicating requires such a delay.

8.2.23. **VER**

Displays the version number and date of the HydroRad firmware.

8.2.24. **ZERODEPTH**

ZERODEPTH measures the current raw reading of the pressure transducer, then records this as the *Offset* used for calculations of calibrated depth (which may also be set with DEPTHCAL). If executed while the HydroRad is at atmospheric pressure,

ZERODEPTH compensates for offset errors due to the effects on the transducer of temperature and barometric pressure.

8.3. GENERAL OPERATIONS

8.3.1. <enter>

Pressing the enter key on a blank line will repeat the last command.

8.3.2. *command

Any command preceded by an asterisk "*" will be passed to the slave unit (if any) for execution. In this manner you can send commands to a slave unit without executing the command to the master unit. This is not needed under normal circumstances.

8.3.3. \command

Any command preceded by a backslash will be passed to PicoDOS for execution. In this manner you can execute any PicoDOS command from within HydroRad. This is not needed under normal circumstances.

WARNING: Although you can use this mechanism to launch another program, or run a PicoDOS batch file, from within HydroRad, this is not advisable. It leads to a disorderly exit from HydroRad, and the computer may not return to HydroRad upon completion of the other program.

8.3.4. BATT

Displays the current supply voltage and charge current (if battery is being charged). This is typically the voltage of the internal battery, but may also be supplied by an external source. If the external source's voltage is higher than the battery voltage, its voltage will be reported. The voltage reported will be somewhat lower than actual voltage of the source, since it is measured after passing through a protective diode.

8.3.5. DEPTH

Displays the current calibrated depth reading in meters.

8.3.6. Filename

Executes the command file *FILENAME.CMD*, if it exists. See section 9 for a discussion of command files. Synonymous with typing *RUNFILE Filename*.

8.3.7. PAUSE Seconds

Used primarily in command files, PAUSE illuminates the red indicator, waits for the given number of seconds (5 if *Seconds* is not specified), then switches the indicator to green.

8.3.8. PICODOS

Exits the HydroRad program and sends control to the PicoDOS (operating system) prompt. Note that if an `AUTOEXEC.BAT` file is present on the flash disk, it will be executed. If the current baud rate is other than 9600, PicoDOS will set it to 9600, unless otherwise instructed in an `AUTOEXEC.BAT` file (see also 6.2 and 6.3).

8.3.9. POWER State

Turns on (state = 1) or off (state = 0) power to the spectrometers. `POWER` may also be used without an argument to display the current status. Any command that initiates an integration will automatically turn on the power first if necessary, and executing `SLEEP` will turn it off, so this is rarely needed in normal use.

8.3.10. PRESSURE

Displays the current raw reading of the pressure transducer. See also `DEPTH`.

8.3.11. RESET

Reinitializes the HydroRad program, which executes any `BAUD` command in `AUTOEXEC.BAT` if it exists, loads the parameters in `HYDRORAD.INI` if it exists, executes the commands in `HYDRORAD.CMD` if it exists, and loads any calibration files that exist.

8.3.12. RUNFILE FileName

Executes a command file named `FILENAME.CMD`. See section 9 for a discussion of command files.

8.3.13. SETDCHAN Channel State

Sets the state of a digital output channel to the value specified in `State`. This command is used mainly for debugging. On older HydroRads without shutter electronics, Channel 1 = underwater connector pin #6, and Channel 2 = underwater connector pin #7. State can be either 0 or 1.

8.3.14. SLEEP Seconds

Turns off the spectrometers and puts the system in low-power sleep for the given number of seconds. If *Seconds* is not specified, sleeps indefinitely. Sleep can always be interrupted by receipt of characters on the serial port, or by the sleep/wake switch.

8.3.15. TEMP

Displays the internal temperature of the spectrometers in degrees C.

8.3.16. TIMES TimeA TimeB TimeC TimeD TimeE TimeF TimeG ...

Displays the most recently used integration time for each channel. If times are specified, they will be stored as if they were the most recently used integration time. Up to the total number of master & slave channels may be specified.

8.3.17. TOM8

Exits the HydroRad program, sets the baud rate to 9600, and enters the TOM8 monitor program. Unlike exiting to PicoDOS with the PicoDOS or QUIT command, this allows exiting the HydroRad program without executing an `AUTOEXEC.BAT` file, if one is on the flash disk. Therefore TOM8 is not affected by any BAUD instructions.

8.4. DATA COLLECTION

8.4.1. ACQUIRE [AUTO/FIXED] Count [SEC] Average BaseName Process Format Dest Channels FirstPix LastPix PixInc FilterType FilterSize

Collects data from all channels, sending the data to the host console by default. This command is very similar to the LOG command, but uses different default settings.

The first (optional) parameter sets the exposure time mode. "AUTO" iteratively tries to find the optimum exposure time for each channel (within the limits set with `INTPARAMS`), which may mean that for each data sample, the instrument may take several measurements. "FIXED" re-uses the last integration time, or the times specified in the "TIMES" command. "SPEED" (default) uses auto-integration for the first data collection, and then makes only one measurement per subsequent data collection. Occasionally, data samples will be over or underexposed, but overall, the data sampling rate will be maximized.

The second parameter, *Count*, specifies the number of samples to take. If the word "SECONDS" (or an abbreviation as short as "sec") appears as the next argument, then *Count* is to be interpreted as a duration in seconds during which data should be collected.

If *Average* is nonzero, only one averaged spectrum will be produced for each active channel. Otherwise each spectrum measured will be sent to the host and/or saved.

If *BaseName* is specified, and *Dest* setting indicates data are to be saved in multiple files, the file name for each channel will be formed from the *BaseName*, followed by a letter indicating the channel (A = 1, B = 2, etc.), followed by an extension indicating the data format. If the *Dest* setting indicates data are to be saved in a single file, the letter indicating the channel will be omitted. If *BaseName* is not specified, the base name will be the date, in the form MMDDYY.

The *Process* parameter controls which calibration steps are applied to data before they are filtered and saved:

- 0 - raw, unprocessed (default for Acquire command)
- 1 - "weak pixel" adjustments
- 2 - dark-current compensation
- 3 - normalized by integration time
- 4 - engineering unit scaling (full calibration)

The *Format* parameter selects the format in which data are output:

-2: spectra saved in binary with CRC checksum and host reply (.BIN extension on files). If the output is to the console, the data is followed by a "?". Within 2 seconds, the host must respond with an acknowledgment of good data "Y", or an indicator of bad data "X". If bad data is indicated, or no response is received in 2 seconds, then the data is re-sent, up to 10 times per channel. (default for Acquire command)

-1: spectra saved in binary with CRC checksum (.BIN extension on files)

0: spectra saved in binary (.BIN extension on files)

1: spectra saved in text (.ASC extension on files)

The Dest parameter selects where data are output:

0: multiple files (Channel letter appended to file name)

1: single file

2: host console (default for Acquire command)

3: host console + multiple files

4: host console + single files

Channels is a string of digits indicating with spectrometer channels are enabled. For example, 124 indicates that channels 1, 2 and 4 are enabled. By default, all channels are enabled for the Acquire command.

FirstPix, *LastPix*, and *PixInc* are used to sub-sample the measured data. They determine which pixels will be included in the output spectrum. If *PixInc* is a positive number, then *FirstPix*, *LastPix*, and *PixIncrement* will correspond to physical pixels. If *PixInc* is a negative number, and a calibration has been imported into the HydroRad (see ImportCal) then *FirstPix* and *LastPix*, and $|PixInc|$ will be 10ths of nanometers. For example, if 400, 2000, and 2 are specified, then the output will consist of pixels 400, 402, 404, 406, ... 2000. If 3500, 8500, and -25 are specified, then output will consist of pixels corresponding to wavelengths at 350nm, 352.5nm, 355nm, 357.5nm, ... 850nm. By default, *FirstPix* = 1, *LastPix* 2047, *PixInc* = 1, corresponding to every pixel.

FilterType can be 0, 1, or 2. A value of 0 (zero) or "off" specifies no filtering. A value of 1 specifies boxcar averaging, in which case each pixel in the output spectrum will be the result of an equally-weighted average of the number of pixels or wavelength range specified by *FilterSize* (rounded up to an odd integer if necessary). A value of 2 specifies Gaussian averaging, where each pixel in the output spectrum will be the result of a normal distribution-weighted average, with a full width at half max (FWHM) equal to the number of pixels or wavelength range specified by *FilterSize*. By default, *FilterType* is 0 and *FilterSize* is 1 (no filtering).

If *FilterSize* is a positive integer, then it will correspond to that fixed number of pixels. If *FilterSize* is a negative integer, then the filter width will be that many 10ths of nm wide. So, a *FilterSize* of 5 specifies a 5 pixel-wide filter. A filter size of -15 specifies a 1.5 nm wide filter. By default, *FilterSize* is 0 (no filtering).

8.4.2. AUTO Channel IntTime

Collects a spectrum to memory from the given channel, automatically seeking the optimum integration time. If *IntTime* is specified, it will try that time first. If not, it will start with the integration time that was last used for that channel (regardless of which command triggered the previous integration). If no *Channel* is specified, it will collect from the last used channel. *Channel* may be entered as a letter, a number, or an asterisk "*" to indicate all channels.

8.4.3. AUX

Collects and shows one sample of data from the NMEA-output auxiliary device, if one is attached.

8.4.4. CHAN Channel

If no *Channel* is specified, displays the most recently used spectrometer channel. If a *Channel* is specified, sets the current channel to that value. *Channel* may be entered as a letter, a number, or an asterisk "*" to indicate all channels. This channel setting will be used as the default channel for subsequent AUTO or INT commands.

8.4.5. FILT FirstPixel LastPixel PixelIncrement Channel

Displays the most recent spectrum collected with INT or AUTO, after applying the current filter (see FILTPARAMS). If *Channel* is specified (or an asterisk "*" for all channels), the most recent spectrum from that channel is shown. Press Control-C, or send an ASCII code 03 to break out of the listing.

8.4.6. GRAPH FirstPixel LastPixel VerticalScale Channel

Displays a crude graph of the most recent raw spectrum (whose numerical values can be viewed with RAW). The X-axis represents pixels numbers over the range specified by *FirstPixel* and *LastPixel*. The width of the graph is fixed at 80 characters. If no *FirstPixel* and/or *LastPixel* are specified, the corresponding values set by the FILTPARAMS command will be used.

The Y-axis represents pixel amplitudes in digital counts. *VerticalScale* specifies the graph's height in lines. The Y-axis always covers the full range of pixel values from 0 to 32767. Therefore the default *VerticalScale* value of 32 is equivalent to 1000 counts per line.

If *Channel* is specified (or an asterisk "*" for all channels), the most recent spectrum from that channel is shown.

Note that because of the low resolution of the display, many details of the spectrum may not be apparent.

8.4.7. INT Channel Time

Collects a spectrum from the specified *Channel*, with the specified integration *Time* (in ms). *Channel* may be entered as a letter, a number, or an asterisk "*" to indicate all channels. If no *Channel* is specified, uses the most recently specified channel (that

displayed by CHAN). If no *Time* is specified, uses the time most recently used by the current or specified channel.

The *Time* parameter may also take the form of **Time*, */Time*, *+Time*, or *-Time*. In this case, the operator specified and the new *Time* argument will be applied to the previous integration time for the channel. So if the previous integration time for channel A was 35 ms, and the command INT, A , *2 was used, channel A would be integrated for 70 milliseconds. This may be useful for intentionally overexposing the spectrometer after a AUTO command, to get better resolution in the UV in UR ranges.

8.4.8. LOG [AUTO/FIXED] Count [SEC] Average BaseName Process Format Dest Channels FirstPix LastPix PixInc FilterType FilterSize

Collects data from all channels, storing the data as specified in the Params settings by default. This command is very similar to the ACQUIRE command, but uses different default settings.

The first (optional) parameter sets the exposure time mode. "AUTO" iteratively tries to find the optimum exposure time for each channel (within the limits set with INTPARAMS), which may mean that for each data sample, the instrument may take several measurements. "FIXED" re-uses the last integration time, or the times specified in the "TIMES" command. "SPEED" (default) uses auto-integration for the first data collection, and then makes only one measurement per subsequent data collection. Occasionally, data samples will be over or underexposed, but overall, the data sampling rate will be maximized.

The second parameter, *Count*, specifies the number of samples to take. If the word "SECONDS" (or an abbreviation as short as "sec") appears as the next argument, then "Count" is to be interpreted as a duration in seconds during which data should be collected.

If *Average* is nonzero, only one averaged spectrum will be produced for each active channel. Otherwise each spectrum measured will be sent to the host and/or saved.

If *BaseName* is specified, and the *Dest* setting indicates data are to be saved in multiple files, the file name for each channel will be formed from the *BaseName*, followed by a letter indicating the channel (A = 1, B = 2, etc.), followed by an extension indicating the data format. If the *Dest* setting indicates data are to be saved in a single file, the letter indicating the channel will be omitted. If *BaseName* is not specified, the base name will be the date, in the form MMDDYY.

The *Process* parameter controls which calibration steps are applied to data before they are filtered and saved (the default setting is to use the LogParams "Processing" setting):

- 0 - raw, unprocessed
- 1 - "weak pixel" adjustments
- 2 - dark-current compensation
- 3 - normalized by integration time

4 - engineering unit scaling (full calibration)

The *Format* parameter selects the format in which data are output (the default setting is to use the LogParams "OutputFormat" setting):

-2: spectra saved in binary with CRC checksum and host reply (.BIN extension on files). If the output is to the console, the data is followed by a "?". Within 2 seconds, the host must respond with an acknowledgment of good data "Y", or an indicator of bad data "X". If bad data is indicated, or no response is received in 2 seconds, then the data is re-sent, up to 10 times per channel.

-1: spectra saved in binary with CRC checksum (.BIN extension on files)

0: spectra saved in binary (.BIN extension on files)

1: spectra saved in text (.ASC extension on files)

The *Dest* parameter selects where data are output (the default setting is to use the LogParams "OutputDestination" setting):

0: multiple files (Channel letter appended to file name)

1: single file

2: host console (default for Acquire command)

3: host console + multiple files

4: host console + single files

Channels is a string of digits indicating with spectrometer channels are enabled. For example, 124 indicates that channels 1, 2 and 4 are enabled. By default, the channels specified in the IntParams "Channels" setting are used.

FirstPix, *LastPix*, and *PixInc* are used to sub-sample the measured data. They determine which pixels will be included in the output spectrum. If *PixInc* is a positive number, then *FirstPix*, *LastPix*, and *PixIncrement* will correspond to physical pixels. If *PixInc* is a negative number, and a calibration has been imported into the HydroRad (see ImportCal) then *FirstPix* and *LastPix*, and $|PixInc|$ will be 10ths of nanometers. For example, if 400, 2000, and 2 are specified, then the output will consist of pixels 400, 402, 404, 406, ... 2000. If 3500, 8500, and -25 are specified, then output will consist of pixels corresponding to wavelengths at 350nm, 352.5nm, 355nm 357.5nm, ... 850nm. By default, the settings specified in the FiltParams command are used.

FilterType can be 0, 1, or 2. A value of 0 (zero) or "off" specifies no filtering. A value of 1 specifies boxcar averaging, in which case each pixel in the output spectrum will be the result of an equally-weighted average of the number of pixels or wavelength range specified by *FilterSize* (rounded up to an odd integer if necessary). A value of 2 specifies Gaussian averaging, where each pixel in the output spectrum will be the result of a normal distribution-weighted average, with a full width at half max (FWHM) equal to the number of pixels or wavelength range specified by *FilterSize*. By default, the "*FilterSpec*" setting specified in the FiltParams command is used.

If *FilterSize* is a positive integer, then it will correspond to that fixed number of pixels. If *FilterSize* is a negative integer, then the filter width will be that many 10ths of

nm wide. So, a *FilterSize* of 5 specifies a 5 pixel-wide filter. A filter size of -15 specifies a 1.5 nm wide filter. By default, the "*FilterSize*" setting specified in the *FiltParams* command is used.

8.4.9. LOGAUTO Count [SECONDS] Average BaseName Process

The LogAuto command has been deprecated: see *Acquire* and *Log Commands*. Also note that in version 1.29, the default mode has switched from a minimum duration in seconds to a count.

LOGAUTO collects data from all enabled channels, repeating the collection the number of times specified in *Count*. Alternatively, the word "SECONDS" (or an abbreviation as short as "sec") may appear as the second argument, indicating that the first is to be interpreted as a duration in seconds during which data should be collected.

Examples:

LOGAUTO,3,1,hydro

For each channel, 3 spectra will be collected and averaged, and the average from each saved in a file with the base name "hydro".

LOGAUTO,30 sec,1,hydro

For each channel, spectra will be collected and averaged, and the average from each saved in a file with the base name "hydro", for a total of 30 seconds.

The exposure time for each channel is set automatically to maximize the dynamic range, within the limits set with *INTPARAMS*. After the optimum integration time is determined, each spectrum is filtered according to the current *FILTPARAMS*, then saved in a file or transmitted to the serial port, depending on the *OutputDestination* set in *LOGPARAMS*. If *Average* is nonzero, only one averaged spectrum will be produced for each active channel. Otherwise each spectrum measured will be saved.

If *BaseName* is specified, and the *OutputFormat* setting in *LOGPARAMS* indicates data are to be saved in a file, the file name for each channel will be formed from the *BaseName*, followed by a letter indicating the channel (A = 1, B = 2, etc.), followed by an extension indicating the data format (see *LOGPARAMS*). If *BaseName* is not specified, the base name will be the date, in the form MMDDYY.

If a value is specified for *Process*, this value will override the *Processing* value set up with the *LogParams* command. This parameter controls which calibration steps are applied to data before they are filtered and saved:

- 0 - raw, unprocessed
- 1 - "weak pixel" adjustments
- 2 - dark-current compensation
- 3 - normalized by integration time
- 4 - engineering unit scaling (full calibration)

Note that when *Seconds* is specified, *Count* is actually a minimum. LOGAUTO only checks each time it finishes the last channel to see whether it has exceeded the

specified time. In the worst case it could finish one cycle shortly before the time limit, then do another measurement on all channels before stopping. So the actual time could be as much as the maximum integration time, multiplied by the number of channels, greater than *Count*. To force LOGAUTO to cycle through the channels only once, set *Count* to 1 (without the *seconds* option).

A pair of control-c characters received through the serial port during execution of LOGAUTO will abort the process.

8.4.10. LOGFIXED IntTime Averages BaseName Process

The LogFixed command has been deprecated: see Acquire and Log Commands.

LOGFIXED integrates each channel for the same fixed integration time, given in milliseconds by *IntTime*. However if *IntTime* is not specified, each channel will integrate for the time of its last integration. In this case the integration times may be different from channel to channel.

The *IntTime* parameter may also take the form of **IntTime*, */IntTime*, *+IntTime*, or *-IntTime*. In this case, the operator specified and the new *IntTime* argument will be applied to the previous integration time for the channel. So if the previous integration time for channels A and B were 135 and 178 ms respectively, and the command LOGFIXED *3 was used, channels A and B would be integrated for 405 and 534 milliseconds, respectively. This may be useful for intentionally overexposing the spectrometer after a LOGAUTO command, to get better resolution in the UV in UR ranges, at the expense of over-saturation in the midrange.

If *Averages* is specified and greater than 1, that number of integrations will be performed and each channel's average spectrum saved. IMPORTANT: See section 10.2 for information about how averaging can affect the quality of your data.

If the *OutputFormat* parameter of LOGPARAMS specifies data are to be saved in files, the files (one for each channel) will be named with *BaseName*, followed by a letter A through D designating channel 1 through 4, followed by the extension *.DAT*. If *BaseName* is not specified, the base name will be formed from the current date, in the form YYMMDD.

If a value is specified for *Process*, this value will override the Processing value set up with the LogParams command. This parameter controls which calibration steps are applied to data before they are filtered and saved:

- 0 - raw, unprocessed
- 1 - "weak pixel" adjustments
- 2 - dark-current compensation
- 3 - normalized by integration time
- 4 - engineering unit scaling (full calibration)

A pair of control-c characters received via the serial port during execution of LOGFIXED will abort the process.

8.4.11. LOGRANGE MinTime MaxTime TimeStep Mode Averages BaseName Process

LOGRANGE repeatedly executes LOGFIXED, over a range of integration times. The first integration on each channel will be for *MinTime* milliseconds. If *Mode* is 1, the second integration will be at *MinTime * TimeStep*. If *Mode* is 0 (zero), the second will be at *MinTime + TimeStep*. Integrations continue with increasing length until the integration time is equal to *MaxTime*. If the last calculated time is greater than *MaxTime*, a final integration will be performed for *MaxTime*. For example, LOGRANGE,20,1000,3,1 will integrate each channel at 20, 60, 180, 540 and 1000 milliseconds.

If *MinTime*, *MaxTime*, or *TimeStep* is omitted, the corresponding value set by INTPARAMS will be used. *Averages* and *BaseName* have the same meaning as with LOGFIXED. IMPORTANT: See section 10.2 for information about how averaging can affect the quality of your data.

If a value is specified for *Process*, this value will override the Processing value set up with the LogParams command. This parameter controls which calibration steps are applied to data before they are filtered and saved:

- 0 - raw, unprocessed
- 1 - "weak pixel" adjustments
- 2 - dark-current compensation
- 3 - normalized by integration time
- 4 - engineering unit scaling (full calibration)

A pair of control-c characters received through the serial port during execution of LOGRANGE will abort the process.

8.4.12. RAW FirstPixel LastPixel PixelIncrement Channel

Displays the most recent spectrum collected with INT or AUTO. Does not apply the filter, but does apply the pixel limits set with FILTPARAMS. If *FirstPixel*, *LastPixel*, or *PixelIncrement* are specified, then these values are used in place of the FILTPARAMS limits. If *Channel* is specified (or an asterisk "*" for all channels), the most recent spectrum from that channel is shown. Press Control-C, or send an ASCII code 03 to break out of the listing.

8.4.13. SHUTTER State Delay

Opens (*Shutter open*) or closes (*shutter close*) the detector shutters, if attached. *State* can be either "open" (1) or "close" (0). *Delay* determines how long, in milliseconds the HydroRad will give the shutters to open or close.

8.4.14. START Command...

If *Command...* is specified, it is executed every *SampleCycle* seconds, as specified in the LOGPARAMS command. Control-C, or switching the Trigger switch to OFF, stops the loop. *Command...* may also be the name of a command file, which would

be executed every *SampleCycle* seconds. A STOP command in the command file will also break the loop.

If no command is specified, the LOG command executes every *SampleCycle* seconds, collecting *SampleDuration* samples each time, as specified in the LOGPARAMS command. When *sampleDuration* samples have been collected, the HydroRad will go into low-power sleep mode until *SampleCycle* seconds have passed since the beginning of the previous collection. This is equivalent to switching the Trigger switch to "ON". Control-C, or switching the Trigger switch to OFF, stops automatic sampling.

8.4.15. STOP

Halts data collection initiated by START.

8.5. FILE OPERATIONS

8.5.1. CAPTURE *Filename*

Opens the file named *Filename*, and copies lines of text to the file as they are typed. Editing keys may be used to edit each line as it is typed. During editing, the prompt changes to *Capture>*. The file is closed when a <control-z> character is received. CAPTURE automatically overwrites any previously existing file called *Filename*. The RadSoft Terminal cut and paste functions, on the Edit menu, may be used to give this command considerable power.

8.5.2. COPY File1 File2

Copies the contents of *File1* to *File2*.

8.5.3. COPY CON *FileName* or COPY CON: *FileName*

Synonymous with CAPTURE *FileName*.

8.5.4. DEL Filespec

Deletes the indicated file or files from the flash disk. Any combination of * and ? wild cards that can be used with MS-DOS can be used with this command. The ? wildcard matches any single character, and * matches any group of characters. For example, DEL, TEST?.* deletes any file whose name starts with "TEST", followed by any single character, and with any extension. TESTA.DAT, TEST2.BIN, TESTA and TESTT.X all match; TEST12.DAT does not. DEL presents a list of files meeting that file specification, and their sizes, then asks "Delete all the above files?". If you press Y it will immediately delete them. Pressing any other key will abort the command.

8.5.5. DIR Filespec

Lists all the files on the flash disk whose filenames are described by *Filespec*. *Filespec* can contain MS-DOS wild cards such as "*" and "?."

8.5.6. ERASE Filename

Synonymous with DEL *Filename*.

8.5.7. REN OldName NewName

Renames the file called *OldName* to *NewName*

8.5.8. TYPE Filename Textmode ShowNames Delay

Transmits the contents of the file named *Filename* via the serial port. *Filename* can contain wildcards. If *Textmode* is specified as 1 or "on" (default), then Carriage Returns and Line Feeds will be expanded to Carriage Return/Line Feed combinations. If *Textmode* is specified as 0 or "off", then the output will be pure binary. If *ShowNames* is specified as 1 or "on" (default="off"), then filename(s) precede the output from each file. If *Delay* is specified, then the HydroRad waits *Delay* milliseconds before displaying the output.

8.5.9. XS [/Q] [/X] [/C] Filename

Initiates an XMODEM send from the HydroRad. It is expected that the user will instruct the host computer to receive. It should synchronize with hosts that support original 128-byte block XMODEM, CRC, and 1k XMODEM. Original XMODEM can be forced with the /X option, or XMODEM 128CRC with the /C option. The /Q option inhibits messages. To cancel a pending transfer, press <control-X> several times.

8.5.10. XR [/Q] [/X] [/C] [FileName]

Prepares HydroRad to receive an XMODEM transfer. It is expected that the user will instruct the host computer to send. It should synchronize with hosts that support original 128-byte block XMODEM, CRC, and 1k XMODEM. Original XMODEM can be forced with the /X option, or XMODEM 128CRC with the /C option. The /Q option inhibits messages. To cancel a pending transfer, press <control-X> several times.

8.5.11. YS [/Q] [/G] FileSpec

Initiates a batch file send using the YMODEM protocol. Sends all files whose filenames match *FileSpec*, which can contain DOS wildcards such as "*" or "?". YS can be forced to YMODEM-G (no error checking/recovery) with the /G option. The /Q option inhibits messages. To cancel a pending transfer, press <control-X> several times.

8.5.12. YR [/Q] [/G]

Initiates a batch file receive with automatic file naming using the YMODEM protocol. YR can be forced to YMODEMG (no error checking/recovery) with the /G option. The /Q option inhibits messages. To cancel a pending transfer, press <control-X> several times.

8.6. AUXILLARY SERIAL PORT COMMANDS

8.6.1. SERCLOSE

Closes the 2nd serial port. Not implemented on all systems.

8.6.2. SEROPEN *BaudRate*

Opens the 2nd serial port at the specified baud rate. Data received from the 2nd serial port will be sent to the first serial port. Not implemented on all systems.

8.6.3. SERSEND *String*

Sends string, including ANSI escape sequences to the 2nd serial port. Not implemented on all systems.

8.7. DEBUGGING AND TESTING

8.7.1. FREEMEM

Displays the amount of RAM available (for debugging).

8.7.2. PIXDELAY

Used only for testing.

8.7.3. SIM State

Turns on or off simulation mode. In simulation mode the actual spectrometer data are ignored, and each integration results in a triangular spectrum whose overall amplitude is proportional to the value of *State*. If *State* is 1, the amplitude will be based on a random value.

8.7.4. TEST

Used for debugging.

8.8. HELP

8.8.1. ? Command or HELP Command

Displays information related to specified command. If no command is specified, lists available commands.

9. COMMAND FILES

HydroRad commands can be loaded and executed from files stored on its flash card, exactly as if they had been received on the serial port from a user. By convention, these files have the extension `.cmd` and are referred to as command files. They are similar to MS-DOS batch files, with the addition that they may specify a real-time schedule for executing commands.

Most command files are executed by typing the file name of the command file, minus the `.CMD` extension. Command files can also be executed with the `RUNFILE` command. Upon startup, HydroRad will automatically execute the file `HYDRORAD.CMD`, if it exists. Also, the file `TRIGGER.CMD`, if it exists, will be executed whenever the trigger switch is engaged.

Command files can be created and edited using a Windows text editor, then downloaded onto the flash card as described in section 6.4.

9.1. GENERAL FORMAT

Each line has one command followed by a carriage return and optional linefeed. Commands have the same format they would have if entered in real time.

9.2. SIMPLE EXAMPLE

```
auto 1 20
auto 2 20
auto 3 20
```

The above example simply determines the optimal integration time for channels 1, 2, and 3. Nothing is saved to the flash disk.

9.3. TRIGGER.CMD EXAMPLE

```
pause 10
logauto 5 samples 1 dive1
```

The above example was used for a diver-operated HydroRad. Whenever the trigger switch is toggled, the HydroRad will wait for ten seconds while the diver gets out of the way. For each channel, 5 spectra will be collected and averaged, and the average from each saved in a file with the base name "dive1". The HydroRad will then return to a waiting state. If the trigger switch is turned off while the command is still in progress, it will be cancelled.

Note that the operation of the trigger switch has changed as of firmware version 1.31. See section 7.2 for details.

9.4. TIMED COMMAND FILE FORMAT

Timed commands are preceded by a time in the form HH:MM (hours and minutes), with a comma separating the time from the command. Note that whereas command arguments may be separated with a space or comma, scheduled commands **MUST** be separated from their times by a comma only.

Lines that contain a time, but no command, instruct HydroRad to repeat the last executed command at the designated time.

9.5. EXECUTION

When a file is run, HydroRad begins by executing commands in the sequence they are found in the file. If the file contains no timed commands, HydroRad simply executes them once in order, then closes the file and returns to interactive mode.

When HydroRad encounters a scheduled command, it goes into low-power sleep mode until the scheduled time, then wakes and executes the command. On its first pass through the file, HydroRad will skip any commands whose times have passed.

HydroRad continues executing commands in sequence; unscheduled commands as soon as they are read, and scheduled commands according to their designated times.

When it reaches the end of the file, or if all the schedule times have already passed, HydroRad will return to the first scheduled command in the file, and wait for that time to arrive on the following day.

If a file contains no timed commands, HydroRad will execute all the untimed commands once, then return to the HydroRad> prompt. If the file contains one or more timed commands it will repeat the schedule every day until halted by the user.

9.6. HALTING EXECUTION

To halt execution of a command file, press <control-C>. You may need to repeat this several times, depending on the command being executed. After one or more control-C's HydroRad will reply

```
Really abort command.cmd ? Press Control-C to confirm.
```

If you press <control-C> again within 4 seconds, execution of the command file will end. If you press a different key, or do not respond with 4 seconds, execution will resume.

9.7. TESTING

HydroRad command files are essentially computer programs, and it can be surprisingly easy to create "bugs" in them. Before deploying a command file of any complexity you should test it to verify it that it behaves as you intend. If your file includes long periods of sleep, you can accelerate its execution by pressing a key (not control-C, unless you want to halt execution) once or twice to wake it from each sleep. It will detect that it woke early, and display the message "sleep interrupted", but will nevertheless continue with the next command, then sleep until the next scheduled time.

You can also interrupt time-consuming LOGAUTO, LOGFIXED and LOGRANGE commands, without halting file execution, by pressing <control-C> once during the command.

9.8. TIMED EXAMPLE 1

```
20:00,logauto 600
21:00,logauto 600
22:00,logauto 300
logfixed 10000
23:30,logfixed 100
```

This file will do LOGAUTO,600 at 8PM and 9PM, Sleeping after it's done each one. At 10PM it will do LOGAUTO,300 immediately followed by LOGFIXED,10000, then sleep until 11:30PM and do LOGFIXED,100. Then it will sleep until 8:00 the following day. It will repeat this cycle daily until instructed to do otherwise.

9.9. TIMED EXAMPLE 2

```
intparams,20,1000
0:00,logrange,20,1000,2
6:00,logauto,300 SECONDS
7:00
8:00
9:00
10:00
11:00
12:00
logfixed,10000
```

Note that example 2 starts with an untimed line. Untimed lines that appear before the first timed line are executed only once each time the file is opened, whereas timed commands are repeated each day. Once all the untimed lines are done, the program waits for the first timed line whose time has not yet past. So if you were to start this file at 5:00, it would execute intparams,20,1000, then wait until 6:00 and do that line.

Lines that have a time but no command will repeat the last command that appears before it in the file. If you started example 2 at 8:30, it would do the untimed line, then at 9:00 it would do LOGAUTO,300.

After doing LOGAUTO,300 at 12:00 in this file, then LOGFIXED,10000, HydroRad will sleep until 0:00 the next day, then do LOGRANGE,20,1000,2.

9.10. REALISTIC TIMED EXAMPLE

```
intparams,20,10000
```

```
filtparams,100,1000,10
00:00,logrange,20,13000,5
6:00,logauto,600 SECONDS
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
```

When it is first started this file will do the INTPARAMS and FILTPARAMS commands, then wait for the next listed hour to start. It will collect 10 minutes (600 seconds) of data every hour during daylight hours, and a range of dark integrations every midnight.

10. DATA PROCESSING AND STORAGE

10.1. CALIBRATION PROCESSING STEPS

HydroRad's operating software can save data in raw form, as fully calibrated engineering data, or in any of several intermediate stages of processing. The same processing, and more, can also be performed by the RadSoft Windows software after data have been transferred from the HydroRad to a computer.

The stages in processing are described below. These steps are always performed in sequence; all the steps up to and including that specified by the LOGPARAMS command are performed before data are saved in files. In addition, multiple spectra may be averaged (see 8.4.9, 8.4.10, 8.4.11), and spectral filtering applied (see 8.2.7) after the specified processing.

10.1.1. Process 1: Pixel Compensation

Step 1 uses information from adjacent pixels to compensate for pixels that are identified during calibration as more unpredictable than others. A small but significant percentage of such pixels are found in most CCD chips. This process may result in a small shift in effective wavelength for these pixels. The worst-case shift is equivalent to 2 pixels, or about 0.6nm. **IMPORTANT:** This process can only work when every pixel within the desired spectral range is available. Therefore if you plan to select a subset of pixels (using the *PixellIncrement* parameter of INTPARAMS) you should select a processing level of 1 or higher so that step 1 will be performed in situ, before the pixels are selected.

10.1.2. Process 2: Dark Offset Subtraction

Each pixel in a CCD produces a characteristic offset, which is a function of temperature and integration time, in the absence of light. HOBI Labs measures the offsets over a wide range of conditions, then distills this information into a set of parameters for each pixel. Processing step 2 is to calculate and subtract this offset from the measured signals.

10.1.3. Process 3: Time Normalization

CCDs are inherently integrating, and their output is proportional to the energy accumulated during their integration time. However most applications call for a measure of power, such as irradiance or radiance. Step 3 is to divide the measured signal by the integration time to convert from energy to average power.

10.1.4. Process 4: Spectral Normalization and Units Conversion

Based on measurements with a well-calibrated standard light source, step 4 compensates for the non-uniform spectral response of the CCD and other optical components, and converts the measured spectra to engineering units.

10.2. CHOOSING THE PROCESSING LEVEL

The level of processing applied by the HydroRad is set by the *processing* parameter of the LOGPARAMS command (see 8.2.15). In most cases, RadSoft can also subsequently perform any processing steps not performed by the HydroRad itself, with a few exceptions:

1) If data files do not contain every pixel within a range, that is if you have set FILTPARAMS's *PixellIncrement* parameter to a value other than 1, it will be impossible to perform the pixel compensation process (step 1).

2) Spectrally filtering data whose dark offsets have not yet been subtracted can seriously degrade their signal-to-noise ratio.

3) Averaging spectra processed to a level less than 3 can degrade their accuracy, although the effect may not be severe if the range of integration times included in the average is modest.

For most purposes, we recommend you perform no processing on the HydroRad, except possibly to limit the range of pixels saved. That is, select level 0, use no averaging or filtering, and set the *PixellIncrement* parameter of FILTPARAMS to 1. Saving complete raw spectra gives the most flexibility and accuracy for later processing with RadSoft or other software. Raw binary files also produce the most compact possible data files, pixel for pixel. However if you process and filter the spectra *in situ* you may be able to save a smaller set of pixels and reduce the overall file size (see 10.9).

The computation time required for processing varies widely depending on the settings of various parameters, from a small fraction of a second to several seconds per spectrum. If your application requires collecting spectra in rapid succession, you may wish to store raw data for later processing.

10.3. CALIBRATION FILES

To apply any of the calibration processing steps, a calibration file for each active channel of the HydroRad must be stored on the flash disk. Calibration data for each instrument and channel are generated during HOBI Labs' calibration, then transferred to HydroRad in the form of an ASCII comma-separated values file. This file must be converted by the HydroRad operating software into binary files of the proper format for each channel. This conversion is performed by the IMPORTCAL command (see 8.2.10). The conversion is only needed once, then the .CSV file can be deleted. The working calibration files are named A.CAL, B.CAL, etc. HOBI Labs normally loads these files at the time of calibration. Note that these files are not the same as the .CAL files that were generated similarly by HRCAL (software that is now obsolete).

10.4. ASCII CALIBRATION FILE FORMAT

The file is split up into sections, which can be in any particular order. Sections are identified by strings in square brackets, e.g. [ID]. The firmware ignores extra lines outside the defined sections, and ignores extra information at the end of lines, as long as

it is separated by a comma. There is one section that identifies the HydroRad, and four sections associated with the calibration of each HydroRad channel.

The equations to which this calibration data applies are:

Do , time invariant Dark Offset = Average Signal from Pixels Do_{low} to Do_{High}

Dt , time variant Dark Offset = Average Signal from Pixels Dt_{low} to Dt_{High}

$DarkCorrection[Pixel] = Do + C[pixel] * (Dt - Do)$

$FixedSignal[Pixel] = FixFunction(Signal[Pixel], F[Pixel])$

$Corrected[Pixel] = FixedSignal[Pixel] - DarkCorrection[Pixel]$

$LinearityAdjusted[Pixel] = Corrected[Pixel] + Adjustment(Corrected[Pixel])$

$Rate[Pixel] = LinearityAdjusted[Pixel] / (IntegrationTime + Offset)$

$EngineeringUnits[Pixel] = \epsilon[pixel] * Immersion[Pixel] * Rate[Pixel] * Scale$

$Wavelength = W_0 + Pixel * W_1 + Pixel^2 * W_2$

10.4.1. Identification

This section identifies the instrument to which the calibration belongs. The first line after the label is taken as the serial number of the instrument. The firmware compares this to the serial number of the HydroRad and warns the user if it's different. The next line is the configuration string.

Example:

[ID]

HR990501

CD4S50L2

10.4.2. Channel Information, Dark Correction, Epsilon, and Immersion Correction

This section begins with the channel letter in brackets, such as [A] for the first channel. The firmware only looks for letters A through D.

Line 1 after the marker contains a string of up to 31 characters that gives the real name of the channel. For example, "Irradiance_down" or "Radiance_up". At this time, these strings cannot contain spaces.

Line 2 contains the units of the calibrated data, e.g. "W/m²/nm" or "W/m²/nm/sr".

Line 3 gives an overall scale factor which is applied to all the data in the channel. This could be used, for example to boost the output of a detector that is put behind a neutral density filter.

Line 4 gives the inclusive range of pixels to be averaged to produce the Time Invariant Dark Factor "Do".

Line 5 gives the inclusive range of pixels to be averaged to produce the Time Variant Dark Factor "Dt".

Line 6 gives the number of the first pixel for which calibration data is supplied.

Lines 7 and up contain, for each pixel: the factor F used in FixFunction, the constant C used to calculate the DarkCorrection, and the values of ϵ (epsilon) and Immersion used in calculating Engineering Units. The firmware will keep reading pixel values from successive lines until it hits a line that doesn't begin with a digit, or until the pixel number reaches 2047.

Example channel information, dark correction, epsilon, and immersion correction:

```
[A]
Ed1, name of the channel, 31 chars max
W/m^2/nm, physical units, 31 characters max
1, overall scale factor
3,18, Do_Low and Do_High
20,35, Dt_Low and Dt_High
1, number of first pixel for which calibration data is
provided
3,-0.01319,0.2019938,1.3991, F[1], C[1], epsilon[1],
Immersion[1]
1,-0.01351,0.2019345,1.3991, F[2], C[2], epsilon[1],
Immersion[2]
1,-0.00243,0.2018741,1.3992, etc...
4,-0.00862,0.2018413,1.3992
...
```

10.4.3. Non-Linearity

The values in this table are used in the linearity correction function Adjustment(Corrected[Pixel]). To speed up calculation time and reduce required memory, values are interpolated from a lookup table. The first two entries, "63" and "128" in the example below, define the X-axis of the lookup table. The rest of the data define the Y-axis of the lookup table. The first Adjustment (1) is at counts=63, the second (4) is at Counts=191 (63+128). The third (6) will be at Counts = 319 (63+256), and so on.

Example non-linearity calibration for channel A:

```
[A NLTABLE]
63,128, 1st lookup value, increment
1, Adjustment factor at Counts = 63
4, Adjustment factor at Counts = 191
6, Etc...
7,
...
```


10.4.4. Time Offset

This single value in this section is the amount of time, in milliseconds, added to the integration time requested by the HydroRad firmware, to account for signal processing delays in the HydroRad hardware.

Example time offset for channel A:

```
[A TIME]
9, Time Offset
```

10.4.5. Wavelength Calibration

This section contains the three constants W_0 , W_1 , and W_2 that are used in the second order equation relating pixel numbers to wavelength in nanometers. In the example below, [A WAVE] indicates channel A. [B WAVE] would have indicated channel B, and so on. The text “W0,” “W1,” and “W2” is optional, and could have been omitted.

Example wavelength calibration for channel A:

```
[A WAVE]
327.835,      W0
0.38022,      W1
-2.192E-05,   W2
```

10.5. DATA FILES

HydroRad saves spectra collected with the LOGAUTO, LOGFIXED, and LOGRANGE commands in files on the flash disk, which can be downloaded via the serial connection to a PC (see section 6.4). Files are assigned a base name of up to 7 characters, to which HydroRad appends a letter indicating to which channel it corresponds (A for channel 1, B for channel 2, etc.), and an extension indicating whether the file contains binary or ASCII data (.BIN and .ASC, respectively). For example a base name of “hydro” on a HydroRad-3 will result in files named hydroA.ASC, hydroB.ASC, and hydroC.ASC containing data from the three channels.

The base name may be entered as part of the command (see the descriptions of LOGAUTO, LOGFIXED and LOGRANGE for details). If no base name is specified, a name will be formed from the current date, in the form YYMMDD. All the spectra saved at any time on a given date are stored in the files named for that date. In the unlikely event the integration time actually starts in one day and ends in the next, the spectrum will be saved under the later date.

Data assigned to files that already exist are always appended to the existing file.

Files may be stored in binary or ASCII format. The format is set with the LOGPARAMS command, and defaults to ASCII.

10.6. ASCII FILE FORMAT

The first line of each data file indicates the model and serial number of the instrument that generated it.

The second line indicates the channel, the name of the channel, and the units of calibrated data produced by the channel. The name and units may not be included if raw data are recorded.

In ASCII files, each spectrum is saved as a line of comma-separated decimal values, as follows:

```
RawTime, Temp, Voltage, Depth, Process, N, Scale, Do, Dt,  
IntTime, FirstPix, PixInc, PixCount, Pixel[FirstPix],  
Pixel[FirstPix+PixInc], ...Pixel[FirstPix+(PixCount-  
1)*PixInc] <return> <linefeed>
```

RawTime is the time of the sample in seconds since 00:00 on Jan 1, 1970. If using Excel to display data, you can use the following formula to convert the time to a conventional date/time format:

```
=rawTime/86400 + DATEVALUE("1/1/70")
```

Temp, *Voltage*, and *Depth* are real numbers representing the internal temperature in C, the supply voltage in volts, and the depth in meters.

Process indicates what steps in the calibration process have been applied to the data. A value of zero indicates the data are raw; 4 indicates they are fully calibrated and in engineering units. Intermediate values indicate intermediate steps in the process.

Scale is a number by which all the pixel values must be multiplied to restore them to their correct values. As of firmware version 1.00, this number is always set to 1.0.

Do, and *Dt* are used in the dark current calculation portion of the calibration procedure. They are needed to calibrate raw data, or to convert calibrated data back to raw.

N indicates the number of samples in an averaged sample and has the value 1 if no averaging was done.

IntTime is the integration time in milliseconds.

FirstPix, *PixInc*, and *PixCount* indicate the range of pixels included in the saved spectrum.

10.7. BINARY-CRC & PROMPTED-CRC FILE FORMATS

The binary-CRC data format was created to allow a real-time data collection system to know if the binary data it is receiving is error-free, by including a binary checksum in the data. In prompted-CRC mode, the real-time data collection system can actually request re-sends of bad data packets.

Binary-CRC data also includes all the information required for displaying the data at its current level of calibration, without requiring an external calibration file.

The Binary-CRC/Prompted-CRC data sequence is as follows:

0CC0	2 bytes 0x0C and 0xC0
<Model>	4 ASCII bytes
<Serial>	12 ASCII bytes
<Channel>	1 byte, Channel A=0, B=1, etc
<FiltType>	1 byte = 0, 1, or 2
<FiltSize>	2-byte signed integer
<CalSource>	12 ASCII bytes
<ChanName>	8 ASCII bytes
<ChanUnits>	12 ASCII bytes
<Wave0>	4-byte integer
<Wave1>	4-byte integer
<Wave2>	4-byte integer
<DepthOffset>	4-byte IEEE floating point
<DepthCoeff>	4-byte IEEE floating point
<RawTime>	4-byte integer
<Temp>	4-byte IEEE floating point
<Voltage>	4-byte IEEE floating point
<Depth>	4-byte IEEE floating point
<Process>	2-byte integer
<N>	2-byte integer
<Scale>	4-byte IEEE floating point
<Do>	4-byte IEEE floating point
<Dt>	4-byte IEEE floating point
<IntTime>	4-byte integer
<FirstPix>	2-byte integer
<PixInc>	2-byte signed integer
<PixCount>	2-byte integer
<Pixel[FirstPix]>	see below
<Pixel[First+PixInc]>	see below
...	
<Pixel[FirstPix+(PixCount-1)*PixInc]>	
<CRC16>	2-byte integer
[Prompt]	optional 1 byte = 0x3F or '?'

Wave0 is the zero-order wavelength coefficient times $10 * 2^6$ (divide by 640.0 to get coefficient). Wave1 is the first-order wavelength coefficient times $10 * 2^{16}$ (divide by 655360.0). Wave2 is the second-order wavelength coefficient times $10 * 2^{26}$ (divide by 671088640.0).

If the value of *process* is zero or one, then the pixel values are 2-byte integers. If *process* is greater than one, the pixel values are 4-byte IEEE floating-point values. The most significant byte of each value is stored first (opposite to the native byte order on DOS and Windows PCs).

Prompt is only sent in Prompted-CRC mode, and only if the data is being sent directly out the serial port. If the host replies with a "Y" or "y", the HydroRad will

continue with other tasks. If the host replies with an "X" or "x", indicating bad data, or does not reply for 2 seconds, the HydroRad will re-transmit the data, up to 10 times.

10.8. STANDARD BINARY FILE FORMAT

Standard Binary files can be converted to ASCII files with RadSoft after being transferred to a PC.

Standard Binary files begin with two lines of text in the same format as ASCII files. The first line indicates the model and serial number of the instrument that generated it.

The second line indicates the channel, the name of the channel, and the units of calibrated data produced by the channel. The name and units may not be included if raw data are recorded.

Spectra in standard binary files contain the same data in the same order as ASCII files, with the addition of a pair of "tag" bytes. The data sequence is as follows:

0FF0	2 bytes 0x0F and 0xF0
<RawTime>	4-byte integer
<Temp>	4-byte IEEE floating point
<Voltage>	4-byte IEEE floating point
<Depth>	4-byte IEEE floating point
<Process>	2-byte integer
<N>	2-byte integer
<Scale>	4-byte IEEE floating point
<Do>	4-byte IEEE floating point
<Dt>	4-byte IEEE floating point
<IntTime>	4-byte integer
<FirstPix>	2-byte integer
<PixInc>	2-byte signed integer
<PixCount>	2-byte integer
<Pixel[FirstPix]>	see below
<Pixel[First+PixInc]>	see below
...	
<Pixel[FirstPix+(PixCount-1)*PixInc]>	

If the value of *process* is zero or one, then the pixel values are 2-byte integers. If *process* is greater than one, the pixel values are 4-byte IEEE floating-point values. The most significant byte of each value is stored first (opposite to the native byte order on DOS and Windows PCs).

10.9. DATA FILE SIZES

File sizes vary widely according to their format, and the number of pixels included. They can be reduced drastically (to as little as a hundred bytes) by setting the FILTPARAMS to select a small subset of pixels, although subsampling requires careful attention to the appropriate processing level (see 10.2).

A good compromise between file size and data security is to save all the raw pixel data in binary form. Saving all 2048 pixels results in spectra of about 4200 bytes. In most cases the number of spectrally useful pixels is closer to 1500, reducing the spectra to about 3200 bytes. With the minimum 4 Mbyte flash card, this gives a practical capacity of over 1000 spectra.

Whereas raw binary files save pixels as 2-byte integers, processed pixels are stored as floating-point numbers requiring twice the space.

ASCII files are the easiest to read, but can be as much as five times larger than raw binary files and two to three times larger than processed binary files (up to 20,000 bytes per spectrum). For many applications even this size is not prohibitive, but clearly the user must consider data capacity for long-term or high duty cycle logging. Also, ASCII files take longer to write to the flash disk, possibly slowing the data collection rate.

10.10. LOG FILE

HydroRad keeps a text file called `HYDRORAD.LOG` on the flash disk that records the dates and times (in a human-readable form) at which it stores data and performs various other actions. This can be useful for post-analysis of data, and troubleshooting. The operating software continuously adds to this file, so you may wish to delete it occasionally. If no `HYDRORAD.LOG` exists, the operating software will generate a new one.

11. FIBER OPTIC CONNECTIONS - SERIES 200 ONLY

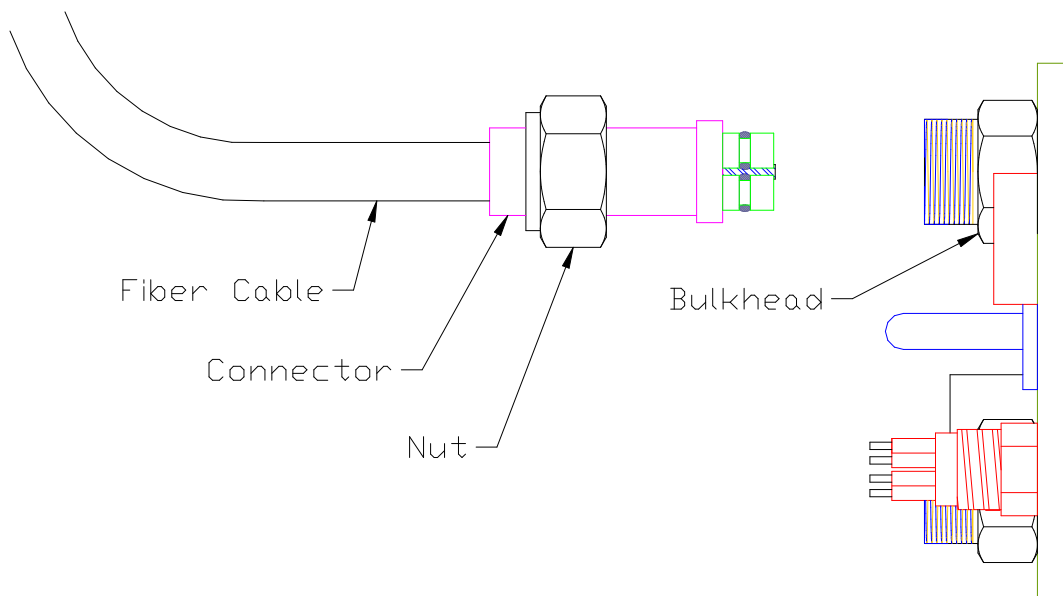
The fiber optic cables on Series 300 HydroRads may not be detached.

The HydroRad fiber optic bulkheads are designed for use only with HOBI Labs HydroRad fiber optic cables.

The fiber optic cables should be detached and re-attached one at a time, to reduce confusion about which fiber goes to which connector, and to reduce the possibility of contamination entering the HydroRad's connectors. The cables cannot be attached or detached while the instrument is submerged.

When detaching and re-attaching a fiber optic connector, there is always the possibility that contamination could enter the connection. Therefore, the fibers should be left attached at all times, if possible.

The HOBI Labs HydroRad fiber optic cable is designed with a stainless steel jacket and o-ring seals to protect and keep water away from the fiber optic connector. Detaching and reattaching a HydroRad fiber optic cable is a delicate operation, and should not be done in the field.



11.1. Detaching a HydroRad fiber optic cable from a HydroRad

- 1) On three and four channel HydroRads, note the cable number being removed to ensure that the same cable is replaced onto the same connector on the HydroRad (see the diagrams in Section 2 for connector numbering).
- 2) Unscrew the connector nut from the HydroRad. Instruments with recent calibrations will require a wrench to loosen the connector nut.
- 3) Pull the connector straight out of the HydroRad. Also remove the $\frac{3}{4}$ " (size 2-018) o-ring from the face of the HydroRad bulkhead.
- 4) Cover the exposed HydroRad bulkhead and connector to prevent the fiber mating faces from becoming contaminated.

11.2. Reattaching a HydroRad fiber optic cable onto a HydroRad

- 1) On three and four channel HydroRads, note the cable number being reattached to ensure that the same cable is replaced onto the same connector on the HydroRad (see the diagrams in Section 2 for connector numbering).
- 2) Visually inspect the fiber terminations sticking out of the bulkhead and inside the connector. The stainless fiber mating faces should have a mirror finish free of blemishes. If the fiber mating faces are smudged or otherwise contaminated they can be cleaned and dried with q-tips soaked in 99% alcohol or Tech Spec lens cleaner (91% alcohol tends to leave smudges). All traces of alcohol or lens cleaner must be quickly removed with dry q-tips to reduce the chance of new smudges and ensure calibrated throughput.
- 3) Carefully inspect the two size 2-009 o-rings on the connector. Replace them with new lubricated o-rings if there is any sign of nicks or scratches on the o-rings.
- 4) Clean the two faces of the connector so they will not contaminate the bulkhead fibers during connection.
- 5) Lay the size 2-018 o-ring on the face of the HydroRad bulkhead.
- 6) Plug in the connector, by first aligning the alignment pin into its hole, then pushing the connector very slowly in, being careful not to pinch the connector o-rings. A gentle rocking motion may be required to prevent the connector o-rings from being pinched.
- 7) Tighten the connector nut firmly, but no tighter than hand-tight.
- 8) With a wrench, tighten the connector $\frac{1}{12}$ turn (15 degrees).
- 9) After 30 seconds or so, loosen the connector, hand tighten, and wrench tight $\frac{1}{12}$ turn again.

12. CUSTOMER SERVICE

If your HydroRad needs to be returned to HOBI Labs for repair, maintenance or calibration, contact HOBI Labs customer service (service@hobilabs.com or call the main office) with the following information at hand:

- Instrument Serial Number
- Reason for return
- Method of return (Federal Express, United Parcel Service, etc.)
- Point of contact
- Date needed (standard turnaround is three-four weeks)
- Delivery address

HOBI Labs will notify you of estimated cost and turnaround time as soon as possible after receiving the instrument. Repairs will not be started until you approve the cost estimate and turnaround time.

For technical support or questions about your instrument, contact our technical support department at support@hobilabs.com or call our main office.